THE PRINCIPLES OF SURGERY AND SURGICAL PATHOLOGY

GENERAL RULES GOVERNING OPERATIONS AND THE APPLICATION OF DRESSINGS

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PREFACE.

The great advances that have been made in recent years in our knowledge of the minute processes and tissue changes in disease, of the causes that underlie them, and of the principles of repair, have established the practice of surgery upon a much broader and more scientific foundation than it formerly had; and the surgeon of to-day who wishes his work to be thorough, intelligent, and fruitful of good results must make this knowledge all his own and must build upon this foundation. Nowhere is this need more keenly appreciated than in our medical schools, where it has long been recognised that the student must gain a thorough knowledge of surgical pathology before he can listen with advantage to didactic and clinical lectures upon special forms of surgical disease and injury.

The makers of even the most recent surgical text-books in the English language have adhered, in the main, to the old division and arrangement of their subjects, and instead of adding to the general group of inflammations, surgical complications, and general surgical diseases, the kindred subjects of the general surgical injuries and diseases of the various tissues, they have separated the latter and combined them with the study of their numerous and varied local forms in regional surgery. Moreover, the general need of keeping the work within relatively narrow limits has led to a correspondingly concise and restricted presentation of the general pathology of each subject, one unsuited to the needs of both the beginner and the practitioner who is in search of detailed information.

On the other hand, the Germans, and to some extent the French, have divided their text-books into two distinct parts, the "general" and the "special"; including in the former not only the general affections and pathology, but also the pathology and principles of treatment of the injuries and diseases of the various tissues, and confining the latter to the consideration of their local manifestations in regional surgery; and the space given to general surgery in their best-known text-books is nearly or quite equal to that given to both subjects in ours.

A consideration of these facts and of the special needs of their students led some of the professors of surgery in New York to suggest the present translation, and as the project met with the approval of others similarly concerned with medical education it was undertaken.

Tillmanns' Surgery was selected as the one best suited for the purpose, and it is hoped that it will receive in its present form the favour it has so widely enjoyed in the original.

John Rogers, M. D.

14 West Twelfth Street.

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TILLMANNS' PRINCIPLES OF SURGERY AND SURGICAL PATHOLOGY.

FIRST SECTION.

GENERAL PRINCIPLES GOVERNING SURGICAL OPERATIONS.

CHAPTER I.

THE PREPARATIONS FOR AN ASEPTIC OPERATION.

a. Definition of a surgical operation. *b.* The indications and counter-indications for undertaking an operation. *c.* Antisepsis and asepsis. *d.* The preparations for an aseptic operation.—Operating room.—Operating table.—Preparation of the patient.—The operator and his assistants.—Sterilisation of the instruments.—Sponges.—Substitution for sponges of aseptic (sterilised) pads of gauze, etc.—Preparation of aseptic dressings.

§ 4. **Definition of a Surgical Operation.**—An "operation," in the broadest sense of the word, means any mechanical interference of the surgeon undertaken with a view to remedy disease, in which interference surgical instruments are used.

A distinction is made between an operation in which a loss of blood occurs and one in which it does not. To the bloodless operations belong, for instance, the introduction of a catheter into the bladder, the crushing of a vesical calculus by the lithotrite, the removal of foreign bodies from the external auditory meatus, from the pharynx, etc.

But, generally speaking, an operation is ordinarily understood to be of the kind that is accompanied by a loss of blood, and this is the kind that is meant here. "Operative surgery," says Diffenbach, "is, of all branches of the healing art, the most suited to arouse enthusiasm in its followers; it is a bloody fight with disease for life—a fight that means life or death."

Every surgeon must have a certain amount of natural talent, and an enthusiastic devotion to his profession. A complete mastery of the

technique, keen senses, a well-trained eye, a delicate touch, and a steady hand, are all indispensable. The plan of the operation must be clearly mapped out beforehand, and during the operation must be quietly and resolutely carried out.

§ 5. **Indications and Counter-indications for an Operation.**—A difficult problem which often confronts the surgeon is to correctly weigh the indications and counter-indications for undertaking an operation. It is often a hard question to decide whether a cure is not possible without an operation; and it is well to consider whether the proposed operation does not carry with it greater dangers than the disease itself, especially in those cases where the annoyances are but slight. The counter-indications for operation depend upon the particular organ which is diseased or upon the general condition of the patient (extreme youth or old age, general weakness, coexisting acute or chronic disease, etc.). Under all circumstances it is necessary to have the consent of the patient for the proposed operation.

The question as to whether an operation should be performed against the will of the patient is answered differently by different surgeons, though the majority of physicians consider that they are entitled, and indeed obliged, in exceptional cases, to perform an operation against the will of the patient—if, for instance, the danger from the operation is much less than that from the continuation of the disease, or if the patient can be saved by the operation from certain death.

To gain the desired end in such cases—or, in other words, to perform the operation—the patient is chloroformed, and upon recovering from the anæsthetic he is usually glad that the operation has been done, even though contrary to his will.

§ 6. **Preparations for an Antiseptic or Aseptic Operation.**—We operate, without exception, according to either antiseptic or aseptic principles—that is, we try to prevent entrance into the wound of substances that tend to cause inflammation and putrefaction. All the decomposing products of putrefaction come under the head of septic matter—sepsis (from σῆψις) meaning putrefaction. An *antiseptic* method of conducting an operation and of treating a wound is one that is directed against the entrance of sepsis, or of septic material, into the wound, or, in other words, prevents infection of the wound. An uninfected wound, a wound which runs the normal course in healing, without inflammation or suppuration, is called aseptic—that is, it is free from septic materials.

By *aseptic* is meant that particular mode of operating and treating a wound in which an attempt is made to keep septic matters—i. e., bacteria and the poisonous products of their metabolism—out of the

wound, so that the process of healing may be without reaction, inflammation, suppuration, or fever. We know that all the processes of putrefaction, that every infection of the wound, that all inflammation and suppuration, are caused by micro-organisms (bacteria). The latter exist everywhere; they float in the air, where they are mixed with the atmospheric dust, they cling to the clothes and the skin of the patient and the operator, they are found on the instruments, sponges, etc. Therefore, if we wish to protect those upon whom we operate from the noxious influence of bacteria, we must take the greatest pains to keep the latter out of the wound, or, if they have already found lodgment in the body, to check their further development, and to destroy them as soon as possible.

The preparations for an aseptic operation must be so managed that every possibility of infecting the wound is avoided by careful antiseptic rules. Hence we must always take pains to most rigidly disinfect the operating room, the table, the part to be operated upon, the hands and clothes of the operator and his assistants, the instruments, sponges, and dressings—in short, everything which comes into direct or indirect contact with the wound.

Antisepsis and Asepis.—During operations in former times, antiseptics were employed much too freely—for instance, in the form of a mist, the so-called spray, or in the form of irrigations—and at the close of the operation the wound was once more energetically disinfected. Our most effective antiseptics, especially carbolic acid and bichloride of mercury, are poisonous, and many patients have died after the operation of carbolic and bichloride poisoning. The too intense irritation of antiseptics endangers the vitality of the tissues with which they come in contact, and renders them less capable of withstanding bacteria; furthermore, serious parenchymatous lesions are thus produced in operations on the organs in the thoracic and peritoneal cavities (Senger). It is right, therefore, to limit the use of antiseptics in operations; in fact, most surgeons aim to avoid them entirely. Disinfection and antiseptic treatment of a fresh wound which has been made by the surgeon is not necessary if the operation is conducted strictly aseptically—that is, if the field of operation, the hands of the surgeon, the instruments, the sponges or gauze pledgets, etc., have been sterilised—i. e., rendered free from micro-organisms. Under such conditions a sterilised solution of common salt of a strength of five tenths to seven tenths per cent., or boiled water, can be substituted for the carbolic or bichloride solutions. If larger amounts of sterilised water are needed, the apparatus of Fritsch is useful. The employment of a six-tenths-per-cent. sterilised salt solution is especially useful in laparotomies (Fritsch).

Asepsis has taken the place of antisepsis in operations, for the reason that a wound which has not been irritated by antiseptics heals much more readily, the secretion is much less, and drainage can more frequently be entirely dispensed with. Furthermore, the process of repair in the wound is quicker with the aseptic than with the antiseptic method; the aseptic cicatrix forms sooner, and is more solid and durable than when the wound has been irritated by antiseptics. When the latter have been used the process of cell division is more sluggish, and begins later.

In the case of wounds treated by the aseptic method, complete healing and the formation of the cicatrix usually occupies eight days; while in wounds in which bichloride of mercury has been used the change from granulation to cicatricial tissue has hardly begun in this time.

Socin, Bergmann, Neuber, and others, were among the first to give up antisepsis for asepsis, though Lawson Tait, and Koberle had long furnished proof that beautiful operative results could be obtained without using antiseptic solutions. But for injuries and wounds already infected, the rules of rigorous antisepsis are to be carried out—i. e., the wound should be thoroughly disinfected with a three- to five-per-cent. solution of carbolic acid or a one tenth to one fiftieth per cent. of bichloride of mercury. At present, for the same reasons, there is a disposition to avoid the use of dressings impregnated with antiseptic materials, such as carbolic acid and bichloride, as the dressings can be most easily and surely disinfected by subjecting them to the action of steam at a temperature of 100° to 130° C. (212° to 266° F.) for a half to three quarters of an hour. This method of disinfection is much surer than when the dressings are impregnated with antiseptic materials, as in dressings thus impregnated bacteria have been detected after a short time. Steam sterilising apparatus have now been universally introduced in hospitals for the treatment of dressings, operating gowns, beds, bed-clothing, etc., and small steam sterilising apparatus can easily be brought into every large surgical ward. The portable steam sterilisers of Straub, H. Settegast, Bubenberg, E. Hahn, and Schimmelbusch are especially adaptable for private practice. In Fig. 1 is illustrated the steriliser of Schimmelbusch, which has been introduced in Bergmann's clinic.

As regards the mechanism of this apparatus, the following should be noted: *W*, the part which holds the water, is filled by a funnel through the tube *T*, up to a marked height. Whatever is to be sterilised is placed in the inner compartment of the apparatus, the latter having a double metallic wall. The cover *D* is screwed on tight. In the

centre of the cover is placed the thermometer, *Th.* The water is heated by a gas flame, and the steam, at a temperature of 100° to 130° C. (212° to 266° F.), enters the inner compartment of the apparatus from above, and escapes through the opening *R* into a lead spiral in a condenser filled with water. The air between the double-walled water vessel and the metallic enclosure, which is protected by asbestos, escapes through the openings at *O*. At the end of the sterilisation the water can be drawn off through the faucet *H*, the cover is removed, and the sterilised article taken out. In order that the sterilised dressings can be kept sterile, the tin vessel devised by Schimmelbusch (Fig. 2) is used. This is provided with a tight cover (*d*) and a great number of holes (*a b*); the latter can be opened and closed at will by a strip of tin. This tin vessel is filled with dressings and placed in the steriliser.

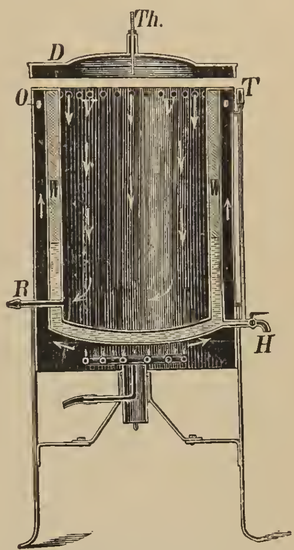

Fig. 1.—Steam-sterilising apparatus (Lautenschläger.)

We shall return again to the subject of sterilisation of the dressings, operation gowns, compresses, etc., and presently describe the sterilisation of the instruments by boiling for five minutes in a one-per-cent. soda solution, the cleansing of the hands, etc. For the disinfection of large articles, such as mattresses, clothes, etc., the disinfector of Rietschel and Henneberg is particularly good. The cleanliness of the operating room and of everything it contains must always be rigorously enforced by the surgeon.

Fig. 2. — Sheet-iron vessel for dressing materials (Schimmelbusch).

Operating Room.—The operating room should be as light as possible, well ventilated, and plentifully supplied with arrangements for washing, receptacles for disinfecting solutions, especially three-to five-per-cent. solutions of carbolic and bichloride (1 to 1,000–5,000), etc.

In larger hospitals it is well to have two operating rooms, one for aseptic operations and the other for infected cases; and it is advantageous to have on the floor of the operating room, which is best made of cement, a gutter arrangement for conducting off the water.

The walls of the operating room must be so built as to be capable of being easily and thoroughly cleansed, and therefore should be covered with oil or enamel paint, or with metal or glass plates. Recesses

and corners which can harbour dust, etc., are to be avoided, on account of the microbes they contain, and pains should be taken not to stir up dust either before or during the operation. Before an operation the air in the room can be moistened by steam from a large spray or steam pipe, if there is one, and thus freed of dust.

Operating Table.—The operating table should be as simple as possible and absolutely clean. In order to facilitate the escape of soiled

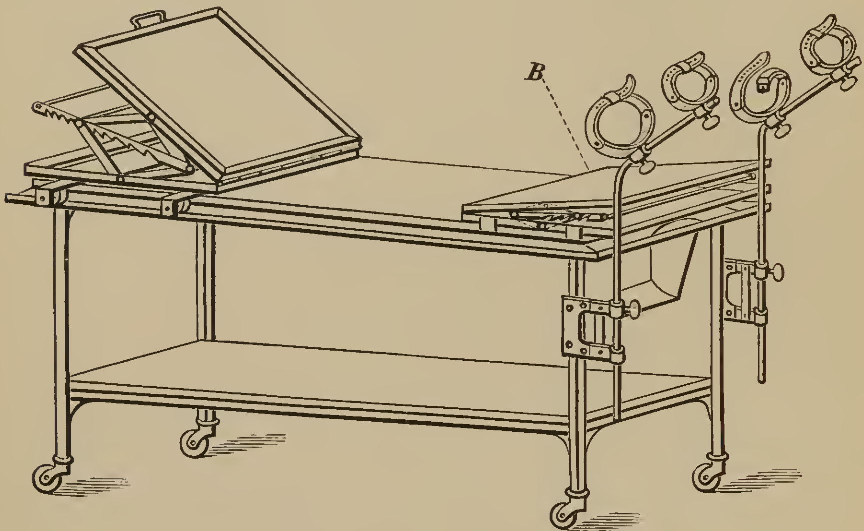

Fig. 3.—Author's operating table.

liquids, operating tables are coming more and more into use which are provided with means to carry off these fluids. Juillard,* Sprengel,† Paul Schede,‡ and Hagedorn # have invented excellent operating tables, with receptacles, buckets, etc., placed under the table to receive the overflow. I consider the operating tables used by Paul Schede, Hagedorn, and Bergmann worthy of recommendation in every way. Operating tables made with an iron frame and a glass plate are very good. My own operating table, illustrated in Fig. 3, has an iron frame with a plate of strong flint glass; the gutter placed around the table conducts away the overflow into a vessel underneath, and the whole table can be readily cleaned. The head-piece, which is easily adjusted, is fitted with a removable glass plate. For elevating the pelvis, a movable framework can be brought into use, made like the head-piece, of glass and iron, and leg-supporters can be very easily

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* Illust. Monatscht. d. Arz. Polytec., 1883, Heft 12.
† Centrl. f. Chir., 1884, No. 30.
‡ Centrl. f. Chir., 1886, No. 8.
\# Ibid., 1887, No. 28.

attached. I have also devised a transportable table with folding legs for private practice and for army use (Figs. 4, 5, 6), which is made of wrought iron, weighs only twenty-five kilogrammes, and is inexpensive.

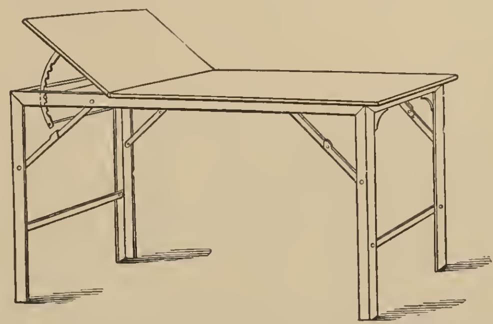


Fig. 4.—Author's transportable operating table for private and military pretice.

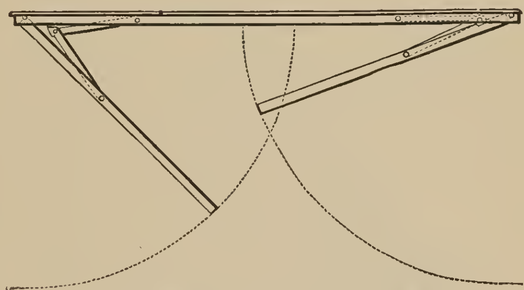


Fig. 5.—Method of folding up the table.

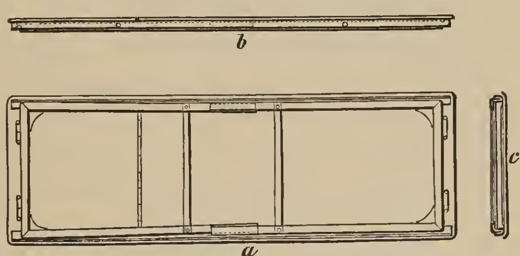


Fig. 6.—The transportable operating table: *a*, seen from below; *b*, the side; *c*, the end.

Trendelenburg has constructed a table which allows the patient to be brought into various positions. For protracted operations —laparotomies, for instance—it is advantageous to use operating tables which can be kept warm, such as metallic tables (Socin) filled with hot water. In this way the patient is kept from losing too much body temperature.

Preparation of the Patient.—The preliminaries for an operation begin with the preparation of the patient. In operations of any magnitude the whole body should be first thoroughly cleansed by means of a warm bath, after which the part of the body to be operated on is scrubbed with soft soap, shaved, rubbed off with ether to remove the fat on the skin, and washed with a three-to five-per-cent. solution of carbolic acid, or an aqueous solution of bichloride of mercury of a strength of 1 to 1,000–1 to 5,000. The scrubbing and disinfecting of the hands and feet especially must be thoroughly and carefully carried out. Instead of brushes which are boiled and kept in a bichloride solution (1 to 1,000), I use swabs

of wood fibre or cotton which are sterilised by heat and burnt after use.

In operations in the mouth the teeth should be thoroughly cleansed by a toothbrush, and the mouth frequently rinsed with a chlorate-of-potash solution of a strength of 5 or 6 to 100, or permanganate of potassium, boric acid, etc. Carious teeth and the tartar which swarms with bacteria, etc., are to be removed. If the operation is in the hypogastric region, in the neighbourhood of the anus, on the urinary and sexual organs, or in the peritoneal cavity, care should be taken to secure a movement of the bowels on the last day before the operation by a dose of castor oil, and about two hours before the operation the rectum should be washed out with lukewarm water injected from an irrigator. When necessary, the bladder should be emptied in advance by a catheter.

The stomach of a patient about to be chloroformed should, if possible, be empty, and in all cases the taking of solid food shortly before the operation should be forbidden, so that the respiratory movements of the diaphragm shall not be interfered with, and troublesome vomiting shall not occur. The entrance of vomited matter into the air-passages has repeatedly caused death during chloroform narcosis.

Fig. 7.—Preparation of the patient for operations on the face and neck.

After the cleansing and disinfecting of the portion of the body to be operated upon has been completed, the patient is then covered with rubber or linen protectives, leaving the field of operation exposed (Figs. 7–10). For this purpose protectives are provided with openings for the arms, legs, and neck, or they are suitably fastened together with safety pins. The linen protectives should be sterilised by keeping them for half an hour in the steriliser at a temperature of 100° C.

In operations upon the face and neck the patient's hair should be covered by a rubber cap, which is made to fit tightly by means of an elastic band, so as to prevent the hair from coming in contact with the field of operation; or, better still, the head may be wrapped in an aseptic gauze bandage.

For operations in the peritoneal cavity, it is better to provide two protectives, as is shown in Fig. 10. Figs. 7 to 10 illustrate sufficiently the excellent plan which has been recommended by Neuber. I cover the neighbourhood of the field of operation with large aseptic compresses (or towels) which have been sterilised in the steriliser by heat

at a temperature of 100° to 130° C. (212° to 234° F.), and are then moistened with a one-tenth-per-cent. solution of bichloride.

If an operation is protracted, especially in cold weather, care must be taken that the patient does not become chilled. If the patient becomes badly chilled, a dangerous or even fatal collapse may be produced, especially after operations in the peritoneal cavity. For this reason it is wise to protect the patient by flannel coverings, warm cloths, etc., and particularly by warming the operating room to about 16°–18°–19° R. (68° to 75° F.). For protracted operations the warmed operating table of Socin, already mentioned, is valuable.

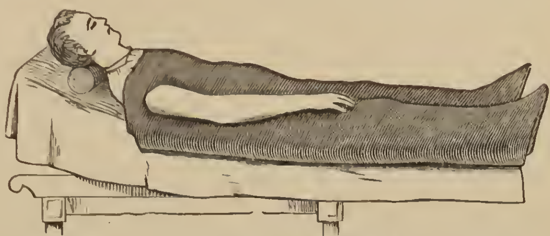


Fig. 8.—Position of the patient in operations on the upper extremity.

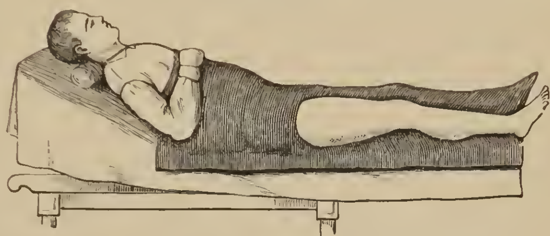


Fig. 9.—Position of the patient in operations on the lower extremity.

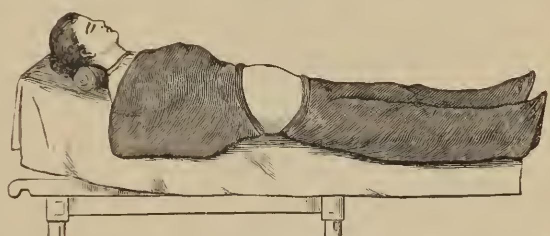


Fig. 10.—Position of the patient in operations in the abdominal cavity.

The best clothing for the operator and his assistants consists of a linen operating gown, the sleeves of which only reach to the middle of the upper arm. Before every operation the freshly washed operating gowns are sterilised for a half to three quarters of an hour in the steriliser by the action of hot steam at a temperature of 100° C. (212° F.). With a view to preserving thorough asepsis, the operator and his assistants must work with bare forearms.

The hands and forearms are disinfected in the following manner (P. Fürbringer): while dry, the nails are first cleansed of visible dirt by a nail cleaner and scissors which are always kept in a ten-per-cent. solution of carbolic acid in glycerine; then the hands and forearms are thoroughly scrubbed with a brush in soap and warm water, with special attention to the ends of the fingers and the part underlying the nails, then rubbed for one minute in seventy to eighty per cent.

alcohol, and before the alcohol has evaporated the hands and forearms are scrubbed with a brush for one minute in a 1 to 1,000 solution of bichloride or a three-per-cent. solution of carbolic.

It is of the greatest importance in the disinfection of the hands to make the mechanical cleansing of the latter as thorough as possible. This is in accord with the researches of Landsberg. For keeping the hands in a good condition Pears's glycerine soap is particularly useful, and if anything more is necessary, the inunction of a small amount of lanolin is excellent. The modern surgeon should give up wearing rings, and in any case always lay them aside before an operation, as they are invariably bearers of infection. A large basin containing a three-per-cent. solution of carbolic or a 1 to 1,000 solution of bichloride should be placed near the operator and his assistants, so that they may constantly keep their hands disinfected, even though they do not come in contact with unclean objects, such as pus, fæces, urine, etc.

Sterilisation of Instruments.—The instruments are best disinfected by boiling them for five to ten minutes in a one-per-cent. solution of soda, the latter substance rendering them less liable to rust than plain water. According to Davidsohn, five minutes is sufficient. The knives are wiped off with a piece of sterilised cotton wet in carbolic solution and placed for only one minute in the boiling soda solution, as they are easily dulled. As wooden handles on instruments are soon damaged by boiling, nickel-plated metal handles are preferable.

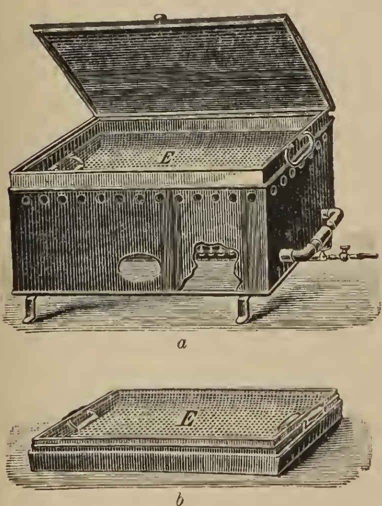


Fig. 11.—Apparatus for boiling instruments (Schimmelbusch).

Instruments are not sufficiently disinfected by simply placing them in carbolic or other antiseptic solution (Gärtner, Kummel, Gutsch, Redard, Davidsohn). A sterilising apparatus for instruments can be made for a small price by any tinman, in the following manner: a large box made of sheet copper, with a removable top, is provided with a tray of tin plate which is punched full of holes; the tray holds the instruments, and has two handles attached to it so that it can be lifted out after the boiling and placed in a three-per-cent. solution of carbolic acid. A very excellent apparatus, devised by Schimmelbusch, is illustrated in Fig. 11, but it is much more expensive. The figure

needs no explanation. At the close of the process of sterilisation the wire tray *E*, which holds the instruments, is taken out and placed in a three-per-cent. carbolic solution contained in a glass dish or tray made of enamel-covered metal.

Before using, I generally wipe off every knife carefully with a piece of sterilised cotton moistened in a three-per-cent. solution of carbolic acid. This is a mechanical means of disinfection which Gärtner has shown to be particularly efficacious. During the operation the instruments should lie in an antiseptic solution, preferably a three-per-cent. solution of carbolic. For this purpose trays are used made of glass, porcelain, and metal. The non-breakable and easily cleaned vessels of enamelled metal which are used in the kitchen are very good for this purpose. After every operation the instruments are scrubbed with a brush and soap in a three-per-cent. solution of carbolic acid and then polished.

Amongst the other sterilising apparatus, those devised by Braatz, Kronacher, Sternberg, and Mehler should be mentioned.

For sponging the wound during the operation, sterilised pledgets of cotton wool or gauze pads should be used, and these are kept wrapped up in sterilised gauze; they are made germ-free by sterilisation at a temperature of 100° to 130° C. (212° to 266° F.) for half an hour, and are decidedly preferable to the ordinary sponges which were formerly employed, as the pads are only used to wipe out the wound once and are afterwards burnt. A large stock of such sterilised gauze pads can be always kept on hand in a bichloride solution (1 to 1,000), or only freshly sterilised pads can be used.

Disinfection of Sponges.—Ordinary sponges very quickly become useless after sterilisation in the hot steam of a steriliser, and they are best disinfected in the following way: After pounding them thoroughly, rinse them in a solution of potassium permanganate (1 to 500–1,000), then soak them for a quarter of an hour in a solution consisting of four fifths to one per cent. of hyposulphite of soda and from one fifth to eight per cent. of pure hydrochloric acid (Keller); then place them for a quarter of an hour more in boiling water or in a boiling soda solution of a strength of one per cent. The sponges are stored in a five-per-cent. solution of carbolic acid or one-tenth per-cent. solution of bichloride of mercury.

Sterilisation of Dressings, Silk, Catgut.—Silk, catgut, drainage-tubes, dressings, and bandages should also be rendered perfectly sterile. Silk should be boiled for half an hour in a bichloride solution (2 to 1,000) or a five-per-cent. carbolic solution, and the other materials can be treated by dry sterilisation—i. e., by keeping them in the dry steril-

iser for half an hour at a temperature of 100° C. (212° F.). For the sterilisation of catgut, see page 88.

The Spray.—Some years ago the operation and the application of the dressings were always carried out under the Lister spray—in other words, in a fine mist of carbolic acid. The management of the hand spray can be understood without further explanation from the illustration in Fig. 12. The steam spray apparatus consists of a vessel containing water, with a spirit lamp underneath. The boiler is filled through the opening at *a* and then closed by a stopper which is screwed in place. At *b* is placed a safety valve, which allows the steam collected in the kettle to escape in case the cock at *c* is turned off. The steam passes from the boiler through a tube closed and opened by the cock *c*, then into a glass containing three to five per cent. carbolic acid, and drives the latter out of the end of the tube in the form of a spray, the direction of which can be changed by means of the handle *d*.

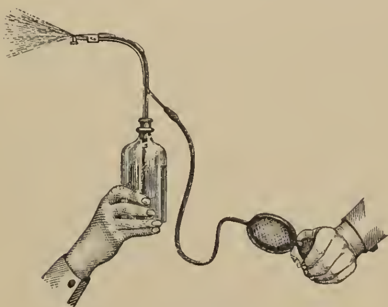


Fig. 12.—Hand-spraying apparatus.

At present the spray, as has been said, is seldom employed, and I, personally, never use it. It has been proved that the results obtained without the spray are just as good as those obtained with it. The spray is troublesome, inconvenient for the operator, and not free from danger to the patient on account of the not unimportant chilling it may cause, and from the danger of carbolic or bichloride poisoning. I sometimes use the spray before a laparotomy when I wish to purify the air of the operating room, and for this purpose I use a steam spray placed as high up as possible. In hospitals fitted with steam or water pipes a very effective spray apparatus can be contrived by connecting the steam pipe with the boiler of the apparatus, and in this way the air in the operating room can be very easily and cheaply rendered germ free—in other words, disinfected.

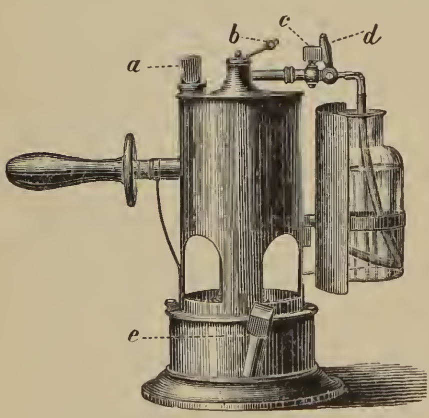


Fig. 13.—Steam-spraying apparatus.

The disinfection of the air of the operating room is ordinarily not necessary, since, in reality, wounds are only infected by contact with the microbes on unclean and insufficiently disinfected hands, dressings, and instruments, but not by the bacteria in the air (Kümmel, P. Fürbringer). I lay great stress upon covering the neighbourhood of the field of operation with sterilised towels, dipped in a one-tenth per cent. solution of bichloride of mercury.

Preparation of the Dressings.—I should mention that the aseptic coverings of the wound, dressings, bandages, etc.—sterilised by heating them at a temperature of 100° C. (212° F.)—are made ready in advance. We shall speak of these in Chapter II. (The Technique of applying Dressings).

Fig. 14.—Metallic or hard-rubber case with spool for aseptic catgut and silk.

Preparations for Operations in Private Practice.—If an operation is to be conducted aseptically outside of a clinic or hospital, as large and light a room as possible should be selected, and thoroughly cleaned and aired. The surest and simplest way of disinfecting a room is to rub down the walls and ceiling with bread (E. von Esmarch), though infected rooms can also be disinfected by burning sulphur after the rooms have been tightly closed. A table, on which to place the patient, should be provided, and covered with some water-tight material and then with sterilised linen; and two or three other tables should be near by, likewise covered with sterilised linen, to hold the instruments, dressings, and wash-basins.

Several wash-basins, soap, absolute alcohol, brushes, towels, sterilised dishes for the instruments, and sponges should be within reach, as well as warm sterilised water in large quantities, chloroform or ether, concentrated carbolic solution, tablets of bichloride, aseptic sponges or gauze pads, drains, silk, catgut, and the necessary instruments sterilised by boiling in a one per-cent. soda solution, and dressings and bandages.

Silk and catgut can be carried about very easily in the simple apparatus pictured in Fig. 14.

CHAPTER II.

THE ALLEVIATION OF PAIN DURING OPERATIONS.—NARCOSIS.—LOCAL ANÆSTHESIA.

History.—Chloroform.—The physiological action and the method of administering chloroform.—Symptomatology of chloroform narcosis.—The possible accidents during chloroform narcosis: death from chloroform.—Treatment of the possible accidents during chloroform narcosis.—Other anæsthetics: methyl compounds.—Ether.—The phenomena of ether narcosis.—Method of administering ether.—The remaining ether compounds.—Nitrous oxide (laughing gas) as an anæsthetic.—Other anæsthetics.—Mixed narcosis.—Local anæsthesia.

§ 7. **The Alleviation of Pain during the Operation.**—A distinction is made between general anæsthesia—i. e., narcosis which is caused by the inhalation of some sleep-producing vapour or gas—and the local anæsthesia which is limited to a particular portion of the body, and produced by the local application of a substance to the part of the body to be operated upon.

Since the earliest times attempts have been made to perform operations with the aid of some means for allaying pain, but the methods were invariably bad, and the action of the remedies which were tried was insufficient. It was not till the year 1846, with the introduction of ether as an anæsthetic, that the dream of the old surgeons was to come true—namely, the performance of even major operations without pain.

As early as the year 1800, Humphry Davy, reasoning from his numerous physiological experiments, had recommended nitrous oxide (laughing gas) as an anæsthetic; and Horace Wells, a dentist in Hartford, tested the remedy in 1844 by extracting twelve or fifteen teeth; but he was not able to introduce the drug as an anæsthetic into general surgical practice.

In ancient times cannabis indica and opium were the chief remedies for controlling pain. Besides these, the pulverised stone of Memphis was used—a kind of marble which, when treated with acetic acid, gives off carbonic acid and in this way produces a certain amount of local anæsthesia. Mandrake root, made into a decoction with wine, was also given internally, and was used especially by the ancient Greek physicians, and in fact was employed

during the middle ages till the end of the sixteenth century. In the middle ages patients were often made to inhale vapours made from hemlock and from the juice of the mandrake leaf. Of interest in this connection are the experiments of Theodoric of Cervia, a learned Dominican, who at his death, in 1298, was Bishop of Bologna. A celebrated surgeon of Salerno, Mazzeo della Montagna (1309–1349), is said to have given the patients whom he was about to operate upon some sleep-producing potion. Porter also speaks of a remedy, without describing it more exactly, which, when inhaled, brought on a deep sleep.

Besides these methods, excessive blood-letting till fainting occurred, compression of the vessels and nerves (Moore), enormous doses of tartar emetic, electricity, animal magnetism, and hypnotism have all been tried. On April 8, 1829, Cloquet is said to have removed without pain a cancer of the breast, together with the axillary glands, from a fourteen-year-old girl during the magnetic sleep, and in 1842 Ward amputated a thigh under the same conditions. Guérineau also performed a painless amputation of the leg while the patient was in the hypnotic slumber.

Many other attempts were made to perform operations painlessly during the hypnotic state, but they were seldom successful; and Kappeler is certainly right when, in explaining the above-mentioned magnetic or hypnotic anæsthesia, he calls to mind that there are individuals whose sensibilities are abnormally blunted, and that insensibility can be simulated.

Two Americans—the chemist Charles Jackson, and the dentist W. L. G. Morton—introduced ether as an anæsthetic into general surgical use, after the inhalation of ether had already been used by others to allay pain and the physiological action of the vapour was known. Furthermore, in 1842 and 1843, W. C. Lang, a physician in Athens, had anæsthetised several patients with ether without publishing his observations. Morton induced Warren, the surgeon of the Massachusetts Hospital, to try the new remedy, and the latter, on October 17, 1846, removed without pain a tumour of the neck under ether narcosis. The knowledge of the new discovery spread quickly to Europe—first to England, then to France, Germany, and the other countries. In England, Robinson, Liston, and Simpson were the first to try it, and they were followed by Malgaigne in France. Schuh was the first in Germany, and on January 27, 1847, he removed, without pain, a teleangeiectasis during ether narcosis.

But the supremacy of ether as an anæsthetic was not to continue long. In November, 1847, Simpson, as a result of some eighty observations, including surgical and labour cases, recommended chloroform, which had already been discovered in 1831 by Soubeiran, in Paris, and had lain unnoticed on the apothecary's shelves for sixteen years. Ether was very quickly superseded by chloroform, and the enthusiasm for the new remedy was tremendous. But soon the first deaths from

chloroform were reported, and the wish for a new anæsthetic became active. Numerous other drugs were tried, but at the present day chloroform and ether hold the field in triumph without rivals worthy of the name. In recent times ether has again gained ground, and is used especially in America, in Lyons, and lately also in England, in Switzerland, and in Germany. In Austria and in Germany, chloroform, and a mixture of chloroform, ether, and alcohol, have the preference. I use ether narcosis in children almost exclusively when there is no disease of the air-passages and lungs, and I am very well satisfied with it. In adults I prefer chloroform narcosis, though neither is without danger, as there have been fatal cases from both; but it must be admitted that fatal cases occur more frequently from the use of chloroform than of ether. Both drugs, we shall see, have their advantages and disadvantages, and the views of surgeons are much at variance as to which to give the preference. My own opinion is that ether should be used when the heart is diseased, and chloroform is preferable in cases with pulmonary lesions. The disadvantages of ether are its great inflammability and its volatility, the latter rendering necessary some special apparatus for its administration. Of the other anæsthetics, the most useful are nitrous oxide, or laughing gas, bromethyl, and recently pental, which is particularly valuable for short operations, and is quite extensively use by dentists. We shall first take up chloroform.

§ 8. **Chloroform Narcosis.** *The Chemical Reactions of Chloroform.*—Trichlormethan ($CHCl_3$) is a clear, colourless, very volatile liquid, with a pleasant, aromatic odour, and a sweet and afterwards burning taste. It can be mixed with ether and alcohol in all proportions, and is soluble in two hundred parts of water. Chloroform is very slightly inflammable, and has at 15° C. (55° F.) a specific gravity of 1.502. It is decomposed by daylight into hydrochloric acid, chlorine, and free formic acid, and is therefore to be kept in the dark, preferably in glass bottles which are covered with pasteboard. By the addition of one half to one per cent. absolute alcohol the decomposition of chloroform can be prevented.

There are three different kinds of chloroform: The officinal German chloroform, chloral-chloroform, and the English chloroform, the latter being purer than German chloroform and three times more expensive.

Only such chloroform should be used as has been previously proved to be pure. The impurities of chloroform consist in adulterations with spirits of wine, ether, etc., in the very dangerous compounds of methyl formed during its preparation, and finally in the decomposition products which develop if the drug is long exposed to the action of light and air (free chlorine, compounds of the hydrocarbons with chlorine, aldehyde, hydrochloric acid, acetic acid, and formic acid). The testing of chloroform is a chemical procedure, which must be done by the chemist or the apothecary; but the surgeon should always make Hepp's smelling test, which is as simple as it is useful. Chem-

ically pure Swedish filter paper is dipped in chloroform, the latter allowed to evaporate, and the dry paper smelled of. If the chloroform is pure the paper has no odour; but if there is a peculiarly sharp and irritating odour the chloroform is impure, and it is either acid from decomposition or it contains the chlorine substitution products of the ethyl or methyl series. Chloroform can also be tested chemically by distillation over crude potash at a temperature of 60° to 61° C. (140° to 142° F.).

Physiological Action of Chloroform.—By inhalation, chloroform vapour is carried to the lungs, or more particularly to the blood, and probably circulates in the blood in chemical combination with the hæmoglobin of the red blood-corpuscles. Chloroform has the power in part of directly destroying the red blood-corpuscles, and in part of robbing them of their ability to take up oxygen and to drive out carbonic acid (Böttcher, Schmiedeberg, and others). The icterus—i. e., hæmatogenous icterus—which Nothnagel observed in animals is probably due to the power possessed by chloroform and ether of destroying the red blood-corpuscles.

Hüter and Witte erroneously ascribed the cause of the narcosis to the change in the blood, especially in the red blood-corpuscles, produced by the action of chloroform; the change in the form of the red blood-corpuscles to spheres with club-shaped processes leads, according to his theory, to the formation of coagula in the cerebral vessels, with a consequent paralysis of the nerve centres. But it is more probable that the blood is only the means of carrying the chloroform, and the chief cause of the narcosis is to be sought in the certain but not yet wholly understood changes in the central nervous apparatus. At any rate, it is certain that these changes do not depend upon disturbances of the circulation, such as a hyperæmia or anæmia in the nerve centres.

The drug is carried to all the organs by the blood as it circulates, including the central nervous system, the brain, and the spinal cord. The ganglion cells are chiefly affected, while the nerve fibres suffer no loss of function, but retain their normal excitability (Bernstein). The sensory ganglion cells are first attacked by the poison, then the motor, as is evident from the final paralysis of the automatic movements of the heart and respiration in a fatally ending narcosis. According to Flourens, the paralysis of the nerve centres begins in the great lobes of the brain; it then attacks the cerebellum, and finally the spinal cord, where first sensation and then motion are lost. The medulla oblongata retains its function the longest, then it also loses its activity, and life comes to an end. The loss of sensation and of the sense of pain is first noticeable in the back and extremities, and last in the cornea with its rich nerve supply.

The changes in the blood pressure and the action of the heart have been carefully studied by Lenz, Scheinesson, Koch, Bowditch, Minot, and others. Chloroform acts upon the vaso-motor centre, and also, in all probability, directly upon the heart muscle and its ganglia. The arterial tension is reduced, the blood pressure sinks, the energy of the heart's action is diminished, and the rapidity of the circulation is lessened. The blood of the whole body becomes more or less venous, and a decrease in oxidation with a sinking of the temperature of the body takes place as a result of the diminished heat production.

Respiration is influenced in two ways by chloroform: in the first place, the direct action of the chloroform upon the terminal branches of the fifth nerve in the mucous membrane of the nose may cause a temporary reflex cessation of breathing, and a noticeable slowing of the heart (stimulation of the vagus), particularly at the outset of the narcosis. In the second place, chloroform acts directly upon the respiratory centre, and the changes thus brought about in respiration are independent of the changes in the circulation. The centre for breathing is first stimulated by chloroform, and later depressed, causing the breathing to become slower and more shallow.

The behaviour of the pupils is of very great importance. The degree of dilatation depends not only upon the amount of light and the degree of accommodation, but also upon the psychical and sensory impressions from the outer world which are transmitted from the brain and cerebellum to the medulla oblongata and from this to the sympathetic, which supplies the dilator muscles of the iris. The dilatation of the pupils occurring at the outset of the narcosis is dependent upon the mental excitement of the patient and upon the reflex stimulation of the fibres of the sympathetic nerve governing the opening of the iris, brought about by the irritation of the branches of the trigeminal nerve in the throat. All these irritations which dilate the pupil cease when sleep or narcosis takes place, and the pupil is therefore contracted.

The uterine contractions during childbirth are not stopped during chloroform narcosis. The influence of the drug upon the muscular fibres of the intestine is not known. Chloroform produces a complete relaxation of the voluntary muscles. It is important to remember that chloroform is excreted in the milk of nursing women, and may be found in the blood of the fœtus.

Chloroform is excreted, according to Zeller, chiefly in the form of chlorides in the urine, and only about a third is excreted as unchanged chloroform by the lungs and kidneys. The excretion of the chlorine derived from the breaking up of the chloroform in the system is just as slow as the excretion of iodine after the external application of iodoform.

Unchanged chloroform can be found in the urine of a patient who has been chloroformed, and if the urine is boiled with Fehling's solution the latter will be immediately reduced to the black copper oxide, and not the red (Hegar-Kaltenbach, C. Theim, P. Fischer). As a result of the destruction of the red blood cells by the action of chloroform, hæmoglobinuria occasionally occurs, though bilirubinuria is more common, for the reason that, owing to the destruction of the red blood-cells, an increased formation of bile colouring matter takes place, which is excreted in the urine.

§ 9. **Technique of Chloroform Narcosis.** *The Method of Administering Chloroform.*—If it has been decided to narcotise a patient for an operation, certain precautionary measures are to be observed. His general condition must be determined by a careful examination of the internal organs, especially the heart and lungs. In cases of extensive pulmonary disease, of pleurisy with effusion, of heart disease, particularly valvular insufficiency and fatty heart, of atheromatous degeneration of the arteries, of alcoholism, of great weakness from loss of

blood, of uræmia, epilepsy, and many diseases of the brain, etc., one must be very careful in the use of anæsthetics, and one must decide in each case whether the narcosis is justifiable. Ether is to be preferred to chloroform for patients with heart disease, and in cases where an operation has to be performed by gas-light.

If possible, the patient's stomach should be empty, since otherwise the vomiting which so easily occurs will disturb the quiet progress of the narcosis and of the operation; moreover, the movements of the diaphragm during the narcosis are interfered with when the stomach is distended. Therefore, without exception, patients should be forbidden to take solid food for from three to four hours before the operation. In England and America it is customary to give stimulants, especially to weak patients, before the narcosis. In many operations. particularly those in the peritoneal cavity and about the region of the anus, etc., the intestine should be previously emptied by a laxative or enema.

The patient should be clothed as lightly as possible, with no constriction in the region of the neck, thorax, or abdomen which interferes with respiration, and the thorax should be uncovered so that the respiratory movements can be watched. False teeth and plates must be removed from the mouth. During the stage of excitement, in the first part of the narcosis, I fasten the patient to the operating table by means of a leather strap passed over the thighs. The horizontal position is usually employed, with the head slightly raised; but for operations on the face, in the mouth, throat, or nose, it is better to place the patient in the sitting posture, with the head held forward to prevent the entrance of blood into the trachea, though some operate with the head hanging back over the edge of the table (Rose). The other methods in use to meet this difficulty are discussed elsewhere (Plugging the Larynx after performing Tracheotomy; see also § 16, Mixed Narcosis).

If the operation must be performed with the patient lying upon his abdomen or side, it will be necessary to watch the respiration and heart action with great care. In order to have good control over the narcosis, and in case of accidents, one should never administer chloroform without the presence of an assistant; in case death should occur from chloroform, as well as for other reasons, it is well to have a witness present.

When the narcosis is to begin, the patient should be quieted by a few words, and told to count slowly and aloud while inhaling the chloroform vapour, and thus an even, quiet breathing is obtained, and the gradual effects of the chloroform can be observed. Chloroform used to be administered by pouring a few drops on a sponge or towel,

which was held over the nose or mouth of the patient; but it is better to use Skinner's apparatus, as modified by Esmarch, with the accompanying flask for sprinkling chloroform in drops (Fig. 15). This apparatus has a wire frame which is covered with porous woollen cloth or thin flannel. Lately I have been using the excellent chloroform mask which I saw used in Kocher's clinic. The wire frame, which is easily sterilised, is made of two pieces, *A* and *B* (Fig. 16), which fold together on a hinge inclosing between them a piece of compress which has been previously spread out on the frame *A*. In administering chloroform, care must be taken not to allow the patient to inhale the vapour in too concentrated a form, but to permit a suitable admixture with atmospheric air. In using the apparatus illustrated in Figs. 16 and 17, the patient cannot help getting the vapour suitably diluted, but the cloth covering of the frame must be as porous and wide-meshed as possible. Furthermore, the mask should never be pressed down so tightly on the face as to prevent the access of air from the sides, and the chloroform should not be sprinkled on the apparatus too abundantly; it should be administered in drops, but continuously. If it is poured out too freely it not infrequently runs on to the neck and breast of the patient, and can cause a very troublesome erythema or burn. I saw such a case as the result of the carelessness of the chloroformer, in which there occurred an extensive and very painful erythema of the back, breast, and shoulders, with a loss of the epidermis as though from a burn. So it is best to lay a light compress on the neck of the pa-

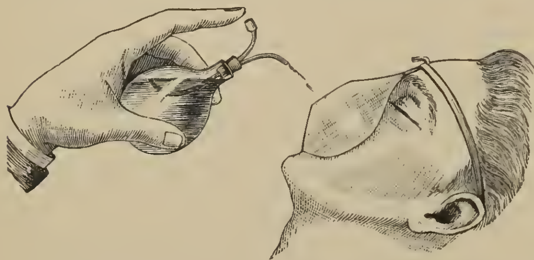


Fig. 15.—Esmarch's apparatus for administering chloroform.

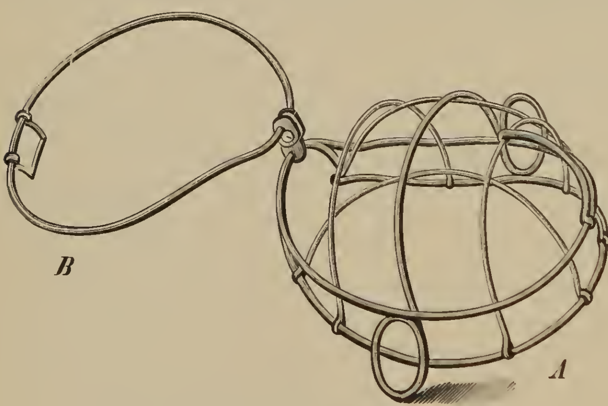


Fig. 16.—Apparatus for administering chloroform.

tient, and to place a piece of cotton or a small sponge on the inner surface of the cloth which covers the apparatus.

Several forms of apparatus have been devised for mixing the chloroform vapour with a known proportion of air, a matter which is of great importance (Bert, Kronecker, Péan, Thiriar, Kappeler). One of the best of these is Junker's (Fig. 18), the description of which is as follows:

FIG. 17.—Apparatus for administering chloroform.

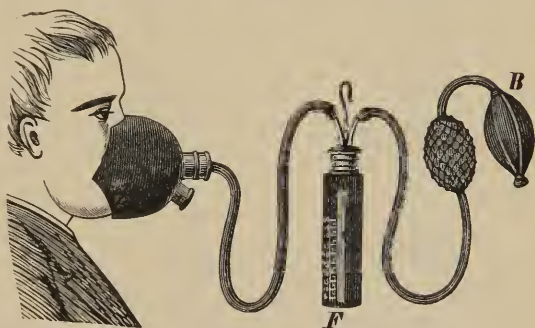


FIG. 18.—Junker's apparatus for administering chloroform.

The Chloroform Apparatus of Junker and Kappeler.—The flask *F* is filled to about one third with chloroform, and is fastened by a hook to a buttonhole on the chloroformer's coat. By pressing the rubber bag *B* a mixture of chloroform and air is supplied to the patient. The mouthpiece which the patient wears is connected with the flask *F* by a rubber tube, and is made of hard rubber or nickel-plated metal, with incisures to fit the nose and chin, over each of which there is a valve to allow for expiration, and two other valves which can be closed or opened to admit air, thus permitting the chloroform-air mixture to be further diluted. Both of the latter valves are placed at the junction of the mouthpiece with the tube from the flask *F*. The expiratory valve is situated in the other and smaller of the attachments to the mouthpiece. Kappeler has lately made an improved modification of Junker's chloroform apparatus, manufactured by the optician Falkenberg, in Constance. The apparatus of Wiskemann likewise gives the proper amount and proportion of chloroform.

The chief advantage of Junker's apparatus lies in the saving of chloroform. As disadvantages, there are to be noted the necessity of using both hands to manage it, the fatigue from squeezing the rubber bag, and the trouble of filling the flask with chloroform. I think evi-

dence is lacking to prove that death from chloroform is less liable to occur with Junker's apparatus than with others; and we know that a considerable number of deaths from chloroform have occurred in the use of such contrivances (§§ 11 and 12).

Suitable instruments should be ready, in case at any time during the narcosis it may be necessary to forcibly open the mouth and pull forward the tongue, which may have fallen back and plugged the pharynx. A wedge-shaped piece of wood is the simplest instrument for forcibly opening the mouth, though Heister and Roser have devised special instruments for this purpose. Heister's is represented as open in Fig. 19. By turning the thumb-screw and separating the two bars which lie in contact when the instrument is closed, the jaws are forced apart. Roser's mouth-gag is illustrated in Fig. 20 as it appears when

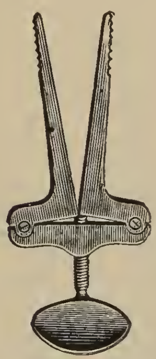


Fig. 19.—Heister's speculum for the mouth.

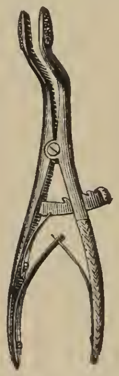


Fig. 20.—Roser's mouth-gag.

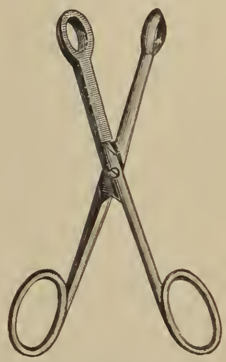


Fig. 21.—Forceps for drawing the tongue forward.

opened. In Fig. 21 is shown an excellent form of pincers for seizing and drawing out the tongue; one of these should be fastened in a buttonhole of the chloroformer's coat.

During the progress of the narcosis the condition of the pulse, respiration, pupils, and the colour of the face must all be carefully watched. Any disturbance of respiration must be immediately met by taking away the chloroform mask, by drawing forward and lifting the under jaw, by opening the mouth, and by pulling out the tongue. If the patient vomits, the head is to be raised, or, better, turned toward one side, to prevent the entrance of vomitus into the air-passages with a resulting fatal asphyxia. After the vomiting has stopped, the mouth should be wiped out with a cloth. The physician administering the anæsthetic should have nothing else to do, and should let nothing divert his attention from his duties.

Decomposition of Chloroform Vapour by the Flame of a Gas-light.—When the vapour of chloroform comes in contact with the flame of a gas-jet there are formed tetrachloride of carbon, hydrochloric-acid gas, and free chlorine (Bosshard), the latter being two gases which according to Stobwasser, when inhaled by rabbits and guinea-pigs, may cause death from œdema of the lungs and hæmorrhages into the lung substance. According to Kunkel, the hydrochloric acid is the chief cause of the discomfort experienced in using chloroform by candle and lamplight. He found chlorine only in small amounts, which were probably set free by the decomposition of hydrochloric acid. To surmount this difficulty, Kunkel recommends abundant ventilation, or, if this is impossible—for instance, during the progress of a laparotomy—the use of a steam spray of lime-water or soda or borax solutions, or towels soaked in such a mixture, to absorb the gas.

Zweifel has observed bronchitis and pneumonia following the administration of chloroform by gas-light, on account of the decomposition of the chloroform ; and he himself lost a patient from catarrhal pneumonia. The fumes are often so strong as to make everybody in the operating room cough, and Zweifel, if he has to operate by gas-light, uses ether, a drug which does not have this drawback.

§ 10. **Symptomatology of Chloroform Narcosis.**—The symptoms of chloroform narcosis have been divided into separate stages, which, though not sharply defined from one another, are each very different. They are (1) the stage of volition, (2) the stage of excitement, and (3) the stage of tolerance. Kappeler speaks of two stages: one of consciousness, and the other of unconsciousness.

The phenomena of chloroform narcosis consist essentially in a change in the perceptions of the special senses, in a disturbance of the intelligence, in a temporary increase of the reflexes and tetanic contraction of the muscles, in changes in the pupils, in a gradual loss of sensation and consciousness, in changes in the circulation and respiration, in a paralysis of the voluntary muscles, and in a diminution in the body temperature.

Sometimes, particularly in the case of weak and exhausted individuals, the chloroform sleep comes on without any intermediate stage, but as a rule it is preceded by a well-marked stage of excitement. The patient becomes restless, and begins to talk, cry out, shout, sing, laugh, weep, etc. Many patients fling their arms and legs about, try to get up, and act as though insane. Gradually the movements of the arms and legs cease ; they become limp ; the face, which has usually hitherto been purple, now becomes pale ; the pupils are contracted, and no longer react to light or mechanical stimulation ; the pulse becomes distinctly slower, the respiration quiet, regular, and at times rather shallow ; the patient is completely insensible, and the operation can begin.

The skill of the chloroformer consists in keeping the patient in this

stage of the narcosis throughout the operation, permitting him neither to awake nor to be overcome by a fatal paralysis of respiration or of the heart. The behaviour of the pupils, the pulse, and the respiration must be carefully watched.

When the anæsthesia is complete, the pupils, which so long as consciousness was not entirely lost began slowly to dilate, now become contracted. By touching the cornea their degree of dilatation will not be affected, since the cornea is without sensation. Sudden dilatation of the pupils during the narcosis is a dangerous symptom, indicating a threatened fatal cardiac paralysis. At times, in deep chloroform narcosis, there occurs an asymmetrical movement of the eye-balls. In such cases, while one eye may remain looking steadily forward, the other may turn slowly inward, outward, or upward. In other cases both eyes may turn either in opposite directions or varying distances in the same direction. The occurrence of asymmetrical movements of the eyes is a sure indication of deep narcosis; the association of the ocular movements returns when the patient awakes.

The heart's action is increased at the beginning of the chloroform narcosis and the pulse becomes more rapid; but with the loss of sensibility coincident with contraction of the pupils and the paralysis of the voluntary muscles, the heart's action becomes weaker and the frequency of the pulse falls below the normal. Kappeler found that the frequency of the pulse, a few hours before narcosis, differed by from four to thirty beats, as compared with that during the narcosis.

According to Kappeler, the pulse-curve obtained by the sphygmograph teaches that the innervation of the circulatory system is diminished during chloroform narcosis, the activity of the vaso-motor nerves is lessened, and the arterial blood pressure falls correspondingly. Hand in hand with the slowing of the circulation and the diminution of the blood pressure there is a loss of body temperature, which, according to the measurements of Kappeler, amounts to between 0·2° to 1·1° C., or an average of 0·59° C.

The behaviour of respiration varies greatly with the individual, but both the frequency and the depth of the breathing diminishes as the administration of the chloroform is prolonged. Chloroform acts locally upon the nerves of the respiratory tract, as well as on the respiratory centre. In any stage of chloroform narcosis, particularly in the first, there may be a cessation of respiration, or its normal course can be seriously interfered with by the tongue falling back against the posterior wall of the pharynx. Retching or vomiting is of frequent occurrence during all stages of chloroform narcosis, but particularly in the first, if the patient has had something to eat a short time previously.

Loss of sensation occurs first in the back and extremities, later in the genitalia, then in the face and head, and finally in the cornea, with its abundant nerve supply; and after the termination of the narcosis sensation returns to these parts in the reverse order.

As a result of the local action of chloroform vapour, the secretion from the mucous membrane of the mouth and nose is increased, though not to the same extent as in ether narcosis, and for the same reason there is also an increase in the secretion of the lachrymal gland. The urine sometimes contains traces of albumen, but seldom of sugar.

After the administration of chloroform and ether to animals, Nothnagel almost always found bile pigment in the urine. Icterus has been observed in patients who have been chloroformed or etherized, and bile pigments are frequently present in the urine. After the internal administration of chloroform, Kappeler examined the urine of twenty-five cases to determine the presence of bile pigments, without finding a trace of them.

The recovery from the narcosis occurs rather quickly, with a sudden dilatation of the pupils. The patients have usually lost all recollection of their surroundings, and are surprised that the operation is finished. They either feel perfectly well, or they complain of unpleasant sensations in the head, of vertigo, nausea, and vomiting—the latter sometimes lasting several days. Many patients after awakening from the narcosis act as though drunk. Women, in particular, are apt to be excited, and weep, or perhaps have serious fits of hiccoughing and hysterical crying. Many patients, particularly children, after awakening fall asleep again, while others cause anxiety by remaining asleep for a long time.

At the close of the operation the patient should be carried as soon as possible into another well-aired room, and should be given very little to drink on account of the troublesome vomiting after the narcosis. For the marked thirst, frequent rinsing of the mouth with cold water is very serviceable. Not infrequently the vomiting is severe during the first twelve to twenty-four, or even forty-eight hours after the narcosis. In such obstinate cases an ice-bag should be laid on the back of the neck and over the stomach, and strong black coffee or iced champagne or small pieces of ice may be given at intervals by mouth, and as a last resort a subcutaneous injection of morphine may be administered in the region of the stomach. Neuber uses a subcutaneous injection of caffeine two or three times a day (0·03 caffeine in a solution of 1·0 caffeine with 12·5 each of distilled water and alcohol). Too much water and ice increases the vomiting, and so should be avoided.

§ 11. **Accidents Occurring during Chloroform Narcosis.**—1. *Vomiting.*—Retching or actual vomiting may occur at any stage of the narcosis,

but especially before the complete loss of consciousness and towards the close of the narcosis. If the stomach is full, vomiting regularly takes place. Occasionally death has been caused by asphyxia, due to the inhalation of stomach contents. During the act of vomiting the patient usually recovers consciousness, thus causing the narcosis and the operation to be prolonged. When vomiting occurs the head of the patient should be turned to one side, and if the mouth is tightly closed it must be opened by force with one of the instruments illustrated on page 22.

2. *Anomalies of Respiration.*—Irregular respiratory movements are generally—in fact almost always—to be expected during the narcosis.

In the beginning of the latter there is not infrequently a cessation of respiration in expiration, generally accompanied by a spasmodic closure of the glottis. As has been mentioned on page 18, this temporary apnœa is caused reflexly by the chloroform vapour coming in contact with the end filaments of the fifth nerve in the nasal mucous membrane. But the danger is greater if respiration stops during the stage of excitement, giving the characteristic picture of asphyxiation: the thorax is as stiff as a board, the jaws are tightly closed, the tongue is drawn back against the posterior pharyngeal wall, pressing down the epiglottis and so closing the larynx, while the face becomes bluish red. Under these circumstances death can result; but such a picture should cause no alarm in one who is experienced, as this disturbance in the respiration can be easily remedied. After the stage of excitement has passed and the patient is fully under the influence of chloroform, respiration can be easily interrupted by the tongue falling backward of its own weight, pushing down the epiglottis and thus closing the entrance into the larynx. The bluish-red colouration of the face in such cases calls attention to an interruption in the respiration.

Linhart saw a singular cause for the asphyxia in a girl who had a very pointed nose and extremely thin alæ nasi. The latter were pressed tightly against the septum on both sides by atmospheric pressure during inspiration and thus closed the anterior nares, and at the same time the mouth could not be opened owing to trismus. The alæ were pried apart with a penknife and air rushed into the nose, making a distinctly audible noise. Linhart believes that the alæ nasi frequently have this anatomical peculiarity.

3. *Disturbances in the Circulation.*—These are extremely dangerous, and sometimes occur at the beginning of the narcosis, but more frequently after the administration of chloroform has been kept up some time; in other words, in the stage of tolerance or deep narcosis. No matter whether the respiration is normal or not, if the radial pulse becomes intermittent and the face pale there is need of the greatest

care to prevent the threatened syncope from proving fatal. It occurs sometimes quite suddenly and without warning, and the impending danger is not foretold by irregularity of the pulse. In a case of chloroform syncope the face turns very suddenly waxy white and corpselike, the cornea becomes dull, the pupils are dilated to their fullest extent and do not react, the radial pulse cannot be felt, the heart sounds are very faint or inaudible, blood ceases to flow from the divided arteries, or the blood that does flow out is in the form of a few dark drops, the muscles are pale and flabby, and respiration ceases. I have several times experienced the anxiety that goes with a threatened death from chloroform, and I am sorry to say I have lost two patients in this way.

§ 12. **The Occurrence and Causes of Death from Chloroform.**—There are no accurate statistics showing the relation between the number of deaths and the number of patients to whom chloroform has been given. The number of published deaths from this cause gives no idea of their frequency, as the fatal results from chloroform are too often kept quiet, and consequently the statistics on this point vary very widely.

Legal Responsibility of the Physician in Cases of Death during Narcosis.—Borntrager, E. Hankel, and Dumont have made noteworthy contributions to the subject of the legal responsibility of the physician in the administration of chloroform and other anæsthetics; and Dumont maintains that the physician is answerable for a death when he administers ether to a patient with pulmonary disease, and chloroform to one with a cardiac lesion. I should not consider this assertion of much legal value, as a correct decision can only be reached after consideration of each case by itself.

Statistics of Death from Chloroform.—I take the following statistics from Kappeler's work on anæsthetics. According to an American, Dr. Andrews, there was one death in 2,723 cases of chloroform narcosis. In eight English hospitals, between the years 1848–1864, 17,000 cases were chloroformed, with one death; and between the years 1865–1869 there were 7,500 cases, with six deaths—a ratio of 1 in 1,250.

There is a very apparent difference in the statistics of the various hospitals. In one hospital a long interval of time will pass with a great number of cases of chloroform narcosis without a single death, while in another, in the same time and with the same number of cases, there are several accidents. This variation in the proportion of chloroform deaths in this or that hospital can be partly explained by the greater or less skill of the one intrusted with the administration of the drug.

Rendle estimates the number of people chloroformed yearly, in the twenty hospitals in London, at 8,000, with about three deaths, or 1 in 2,666.

Billroth had his first fatal case after giving chloroform 12,500 times.

Nussbaum gave it 15,000 times without a death. Dr. Coles, in a report to the Medical Society of Virginia, gives the following statistics:

ANÆSTHETIC.	Deaths.	Number of times used.
Ether	4	92,815, or 1 : 23,204
Chloroform	53	152,260, or 1 : 2,873
Mixture of chloroform and ether	2	11,176, or 1 : 5,588
Methylene bichloride	2	10,000, or 1 : 5,000

To get a better knowledge of the causes of death from chloroform, Kappeler collected the records of one hundred and one cases, seventy-eight of which were men and twenty-two women; in one case the sex was not mentioned. Of these one hundred and one, forty-three died before the full effect of the chloroform was obtained, forty-seven in deep narcosis, and in eleven the particular stage of the narcosis is not mentioned. The amount of chloroform used is known in forty-six cases, and it was, as a general thing, small, averaging 11·1 grammes, the smallest amount being twenty drops, and the most thirty to sixty grammes. Very diverse methods of administering the chloroform were used, such as sprinkling it on simple pieces of cloth, cotton, or the regular apparatus of Skinner, Esmarch, and others.

As to the age of the patients who were operated upon for different diseases, two died under five years of age, twelve between the ages of five and fifteen, nineteen between sixteen and thirty, twenty-one between thirty-one and forty-five, twenty-five between forty-six and sixty. Of those over sixty years of age one died. In twenty-one cases the age is not given.

Causes of Death from Chloroform.—The *causes of death* from chloroform are very varied, and frequently the chloroform is not to blame at all. If a patient chokes from aspirating vomitus into the trachea and bronchi, or from getting a set of false teeth into his larynx during the chloroform narcosis, this sort of death is plainly not due to the chloroform. A certain number of sudden deaths take place even before the administration of the chloroform has been begun. Desault, for instance, was about to perform a lithotomy, and, to demonstrate to the spectators his line of incision, drew his finger-nail over the patient's perinæum, whereupon the latter suddenly uttered a loud cry and died instantly. Cazenave was going to perform an amputation, but the patient was in such a state of nervous depression that he did not venture to give him chloroform, and only pretended to do so by holding a cloth, with nothing on it, over his face. Suddenly his respiration stopped, his heart ceased to beat, and the patient was dead. The first patient to whom Simpson attempted to administer chloroform died under similar circumstances. The attendant who was to bring the chloroform into the operating room stumbled, fell, and broke the bottle containing the drug, and spilled all the chloroform on the floor. The operation, which was for hernia (herniotomy), had to be performed without chloroform, and at the first incision through the skin the patient died. It is difficult to give a satisfactory explanation for these sudden deaths. Furthermore, in cases which must be operated upon after having lost a great deal of blood, if death occurs from cardiac paralysis during the administration of the chloroform, it is not to be put down to the anæsthetic.

We must separate all these cases of death occurring during the narcosis from the cases of death really caused by chloroform. In the latter, death is caused principally by paralysis of the heart (syncope) or paralysis of respiration (asphyxia). In cases of death from syncope, the heart's action ceases before or almost at the same time that respiration does; but in cases of death from asphyxia the respiration ceases first and the heart's action afterwards. In any case, whether the result of syncope or asphyxia, death can occur before or during the time that the full effect of chloroform is obtained, and therefore at the beginning or at any period of the narcosis proper.

Of the twenty-three cases of death from syncope which Kappeler collected, fourteen patients were completely and nine partially chloroformed. Death from asphyxia occurred ten times during complete and seven times during partial narcosis. If death occurs in the first part of true narcosis, and therefore before the full effect of chloroform has been obtained, the cessation of respiration or the cessation of the heart's action is in all probability dependent upon the trigeminus-vagus-reflex, as mentioned on page 18. Death from asphyxia in the stage of incomplete narcosis may also be caused by spasmodic retraction of the tongue over the entrance of the larynx, or by spasm of the abdominal muscles or of the diaphragm. Death from chloroform in the stage of deep narcosis is caused by the direct paralysis of the circulatory and respiratory centres in the medulla oblongata; but death from asphyxia during this same stage can also occur if the tongue falls back over the entrance into the larynx.

How far impure chloroform is responsible for death in this or that case is difficult to say; but it is worth remarking that certain persons, even without known pathological reasons, take chloroform badly, or, in other words, show an idiosyncrasy towards it. It has been proved by numerous experiments that it is particularly dangerous to inhale chloroform vapour in too concentrated a form, and Snow, Sanson, and the English committee which investigated the cases of death from chloroform published an urgent warning on this point. Lallemand, Perkin, and Duroy showed that mammals will quickly die if they are made to breathe a mixture consisting of eight parts of chloroform to one hundred of air, while they can safely breathe a four-per-cent. mixture. According to Snow, five parts of chloroform to ninety-five parts of air can be safely inhaled, but mammals will die if the mixture is made one of eight or ten per cent. by volume. According to the English Chloroform Committee, the drug should only be inhaled in the strength of three and a half to four and a half per cent., and never in the form of concentrated vapour, the latter being the chief cause of the sudden reflex stoppage of respiration and slowing of the heart from stimulation of the filaments of the trigeminal nerve in the nose and throat.

Effects of Chloroform and Air Mixture.—P. Bert has recently studied the action of the chloroform and air mixture upon dogs. Two grammes of chloroform vapourized in one hundred litres of air produced no noticeable effect; four grammes of chloroform in one hundred litres of air were inhaled for nine and a half hours with a loss of 4° to 5° body heat; six, seven, and eight grammes of chloroform in one hundred litres of air produced a marked loss of sensation and temperature, and the animal died after seven hours with a temperature of 30° C. (86° F.). If the proportion was 10 to 100,

there was a complete loss of sensation within a few minutes, and the animal died after two to three hours, with a constant diminution of temperature. If the proportion was 14 to 100, the animal died in an hour and a quarter ; if 18 to 100, in twenty-five minutes ; if 20 to 100, he died immediately and very suddenly. Therefore, according to Bert, the proportion of chloroform to air for anæsthesia should be 10 to 100, but instant death will occur if it reaches 20 to 100. In general, he recommends that a strong dose of chloroform be first exhibited to induce sleep quickly, which can then be maintained by a weak mixture of chloroform and air, the proper proportion being ordinarily a mixture of eight grammes of chloroform to one hundred litres of air. St. Martin constructed, for the purpose of mixing chloroform and air, a somewhat complicated apparatus, made of two gasometers which are alternately filled and emptied. The air, as it enters, passes over a flask containing a known amount of chloroform and is thus mixed with the vapour. The inhalation is conducted by means of a hard-rubber mouthpiece fitted with a double valve. Péan has tried the method on men and considers it useful, the narcosis seeming to progress very quietly. At all events, the experiments of Bert show that we use our anæsthetics in much too large amounts.

Chloroform Poisoning.—Acute chloroform poisoning, which follows drinking large amounts of chloroform, has been observed, particularly in small children, but the children generally recover with proper treatment—artificial respiration, washing out the stomach, etc.

The Influence of Pathological Conditions over Death from Chloroform.—What pathological conditions favour the occurrence of death from chloroform, and what does the post-mortem examination teach on this subject ?

In general there may be mentioned, as dangerous complications of chloroform narcosis, fatty degeneration of the muscles of the heart, valvular lesions, atheromatous degeneration of the walls of the vessels, particularly of the coronary arteries, anæmia, chiefly as a result of excessive loss of blood, chronic pulmonary disease, such as emphysema, diseases of the kidney (Morbus Brightii), and chronic alcoholism. In all such cases the narcosis must be conducted with the greatest caution. Fatty degeneration of the muscles of the heart is particularly dangerous. Sanson found fatty heart in eighteen out of fifty-six cases of death from chloroform, and Kappeler's statistics show it sixteen times in sixty cases.

I do not underestimate the important *rôle* that fatty degeneration of the heart plays in the causation of death from chloroform, as I can see that this kind of a heart succumbs quicker to the action of chloroform than a sound one, but still I think that the influence of this disease in causing death from chloroform is often exaggerated. We know that a slight amount of fatty degeneration of the heart is very common, and that, on the other hand, in many well-marked cases the narcosis causes no trouble. Nothnagel, Ungar, Strassman, and Ostertag have shown that dogs kept for hours, during several days in succession, under the influence of chloroform. die from extensive fatty degeneration, the autopsy showing fatty degeneration of the heart, liver, kidneys, voluntary muscles, stomach, and mucous membranes. Drunkards, as a general thing, bear the narcosis badly, and it is characteristic for them to show marked disturbances of the nervous and muscular system, with threatened cessation of respiration, and with great tendency to collapse.

But with them the chronic endarteritis (atheroma), particularly of the coronary arteries, is responsible for the occurrence of death. The severer forms of acute or chronic anæmia increase the chances of death from syncope, and it is well known that the activity of the central nervous system depends upon the amount of blood circulating through it, and the proportion of oxygen which it contains. If two animals of the same size are taken and the same amount of chloroform is given to each, and venesection is performed upon one, the latter will die before the former.

The Results of Autopsy in Cases of Death from Chloroform.—The autopsy in cases of death from chloroform generally reveals little that is characteristic, and often gives no satisfactory explanation of the cause of death. Not infrequently the above-mentioned pathological changes in the organs are present, and are more or less correctly considered to be responsible for the accident. The blood is ordinarily uncoagulated and dark coloured, but microscopic or chemical examination of it has hitherto given no satisfactory explanation for death. It is worth noting, however, that, as a result of the disturbance of respiration, the blood is overloaded with carbonic acid. An observation made by Recklinghausen is interesting in this connection. In three cases he found bubbles of gas in the great venous trunks and in the heart, and in each instance death occurred very quickly after taking a very small amount of pure chloroform, the pulse stopping suddenly, while shallow breathing continued for a short time afterwards. It could not be determined what the bubbles of gas were, and Sonnenberg was unable to elucidate this point by experiments upon animals. The experiments only showed that nitrogen under certain circumstances is set free within the blood-vessels. Before the above observation was made, Von Langenbeck and Pirogoff had also noticed considerable amounts of gas in the large venous trunks and in the right ventricle of the heart in cases of death from chloroform. Kappeler's more recent researches have shown that this evolution of gas is not peculiar to the death from chloroform, but is due to post-mortem changes. If the gas is set free to any extent during life, or if its presence was caused by venesection, death is produced by mechanical interference with the heart's action, as happened, for example, in Pirogoff's case. Mention should be made of the fact that Winogradow found granular degeneration of the ganglia of the heart and of the nerve cells of the brain and the spinal cord in both men and animals after death from chloroform.

The Cause of Death from Chloroform.—From what has been said, it follows that chloroform is a nerve poison which occasionally produces death, particularly if it is inhaled in too concentrated a form, either by reflex paralysis of the heart or respiration, or by direct paralysis of the centres in the medulla oblongata governing circulation and respiration. According to Winogradow, chloroform causes a granular degeneration of the heart ganglia and the nerve cells of the brain and spinal cord. The dose of chloroform necessary to produce death varies with the constitution of each case, but pathological conditions of the nervous system, the heart, vessels, and the lungs, favour its occurrence. In general,

death may result from reflex paralysis of the heart or respiration, at the beginning of the narcosis, even from a small dose, while fatal paralysis of the centres governing circulation and respiration only occurs after larger doses. Since fatty degenerations of the liver and heart are produced by prolonged narcosis, it is probable that these conditions tend to cause death (Nothnagel, Ungar, and Strassmann).

According to Ostertag, death from chloroform is chiefly produced by a fatty degeneration of the heart and an overloading of the blood with carbonic acid, as a result of the disturbances in respiration caused by changes in the respiratory muscles. According to R. Evans, the greater number of the deaths depend upon the overloading of the blood with carbonic acid, which does not begin in the lungs, but in the capillaries of the rest of the body. In a few cases death from chloroform can be caused by an abundant formation of gas (nitrogen). The other causes of death from chloroform may be ascribed to negligence. To this class of cases belong those which are choked by vomited matter, foreign bodies (plates of false teeth), by the tongue falling back upon the entrance to the larynx, etc.

Amongst the cases of death for which chloroform has been responsible, some might possibly have been prevented if more care had been used in the administration of the drug; but in many cases actual pathological changes in the brain, circulatory or respiratory system really brought about the fatal result.

Lastly, it is certain that there are dangerous impurities in chloroform, notably the compounds of methyl, which also occasionally cause death; but. unfortunately, our knowledge of this subject is very scanty. The assertion that chloroform produces death by depriving the blood of oxygen, or by preventing the blood from taking it up (Robin, Chapman, and others), appears not to be correct, judging from Knoll's experiments. The form of death noticed in a few cases, which came on after three or four days of collapse, is explained by the fact that disturbances of metabolism take place which produce the fatty degeneration of the viscera previously mentioned (Kast, Mester, and others).

Narcosis with a Mixture of Chloroform and Oxygen.—J. Neudörfer tries to explain the common accidents and fatal results from chloroform narcosis in the following way: The affinity of hæmoglobin for oxygen is not constant, and varies with the condition of health, being now less, now greater, according to the general vitality of the individual; and so, according to Neudörfer, when this affinity is weak the hæmoglobin's power of absorbing oxygen is more influenced not only by the oxides of carbon and nitrogen, but also by other gases and vapours, by temperature, and by atmospheric pressure, than when the affinity is stronger.

When chloroform is administered to an individual whose hæmoglobin

has a relatively weak affinity for oxygen, and an atmosphere is given him to breathe which is charged with twenty per cent. of chloroform, there will be twenty volumes of the latter to every eighty volumes of the air he gets. The blood gets only sixteen per cent. of oxygen, instead of the usual twenty per cent., and so the hæmoglobin, already having a weakened affinity for oxygen, can take up little or none, and the chloroform exercises its poisonous effect all the more easily. Neudörfer recommends a three- to ten-per-cent. mixture of chloroform and oxygen as the least dangerous way of giving the drug. He makes the oxygen with the apparatus of Limousin, by heating chlorate of potash and peroxide of manganese, and then stores the oxygen in a rubber bag. As soon as the latter is filled, enough chloroform is added by a pipette through a stop-cock to bring about the required proportion of chloroform and oxygen, and the bag is shaken to make the chloroform vapourise quickly.

For inhaling the mixture, Neudörfer uses a mask with two valves which open and close in opposite directions. Kreutzman also likes this mixture.

§ 13. **Treatment of Common Accidents Occurring during Chloroform Narcosis.**—We have seen that the behaviour of the respiration, pulse, and pupils during the narcosis should be watched with the greatest care. Death from chloroform takes place either from a primary cessation of respiration followed by cessation of the heart's action, or the heart stops before respiration, or both respiration and heart stop simultaneously.

When threatening symptoms appear, it must be our aim to bring the irregular or failing respiration and the weak or non-recognisable heart action back to the normal. In all such cases the administration of the chloroform should be immediately stopped.

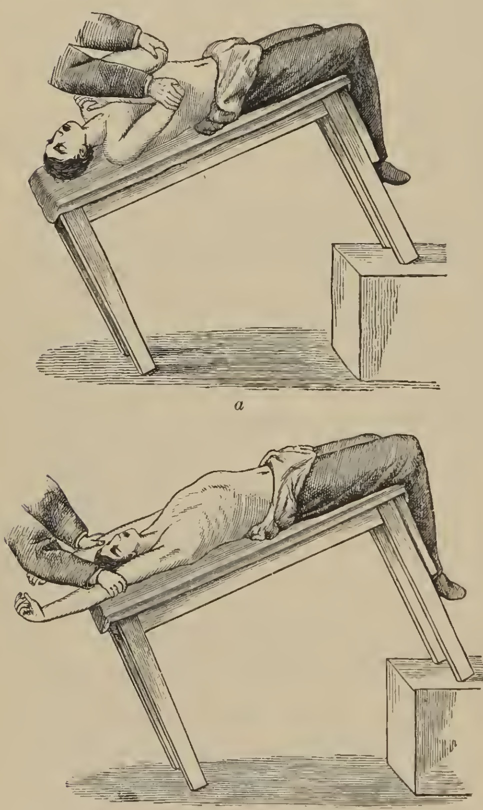
Fig. 22.—The manner of pushing forward the lower jaw for threatened asphyxia.

Overcoming Mechanical Interference with Respiration.—The impediment to respiration may, in the first place, be caused by the occlusion of the opening into the larynx by the tongue. In order to free the air-passage in such a case we have three means: (1) Push forward and raise the under jaw; (2) draw out the tongue; (3) elevate the thorax and let the head and neck fall back (Howard).

To draw forward and lift up the under jaw, seize the latter behind the angle and push it forward and upward (Fig. 22). By this procedure the tongue and hyoid bone are drawn forward, rendering the hyo-epiglottic ligament tense, and this immediately lifts the epiglottis and opens the entrance to the larynx. The tongue forceps illustrated in Fig. 21 is another means of effecting the same result; or a loop of

thread may be similarly used, or a pointed hook may be passed behind the middle of the body of the hyoid bone to draw it forward (Braune). It is usually a good plan to pass the forefinger down to the epiglottis and by raising it open the larynx.

Fig. 23.—Artificial respiration.



a

b

Fig. 24.—Artificial respiration (Silvester).

By Howard's plan of extending the head and neck backward, the point of support of the tongue, which had fallen back when the patient was in the horizontal position, is changed from the posterior wall of the pharynx to the hard palate or the boundary between the hard and soft palates, thus making free for the stream of air the space between the root of the tongue and the posterior pharyngeal wall.

Artificial Respiration.—If these measures are not enough to restore the interrupted breathing, artificial respiration must be begun immediately. Every second increases the danger of the threatened death, particularly if the pulse is irregular and if the face becomes deadly pale or bluish. Artificial respiration is performed with the patient in the position indicated in Fig. 23. The operator grasps the lower portion of the thorax and makes vigorous rhythmical expiratory movements by pressing together the lower lateral portions of the thorax. At the same time the lower jaw is elevated and the tongue drawn forward.

Silvester's method for performing artificial respiration is better

(Figs. 24, *a*, *b*). The patient is placed as quickly as possible in the horizontal position, or with the head directed downward; the operator stands behind the patient, and, grasping the arms, flexed at the elbow, presses them laterally against the chest and then draws the arms backward till they are stretched out horizontally above the head. In this procedure the ribs are raised by the traction of the pectoral muscles.

Schüller has recommended grasping the arch of the ribs on both sides, and, after vigorously raising them, pressing them down against the thoracic cavity. Kraske has shown that, even after the heart has stopped beating, a kind of circulation can be kept up for a certain length of time by artificial respiration and by compression of the heart while the head is kept lowered. The deep inspiratory movements aspirate the venous blood into the right auricle.

Electrical stimulation of the phrenic nerves is another method of resuscitation (Duchenne). The electrodes of an induction apparatus are moistened and placed on either side of the neck, at the outer border of the sternomastoid muscle, which is pressed somewhat towards the median line, and near the lower end of the scalenus anticus. This stimulates not only the phrenic nerves, with the muscle they supply (the diaphragm), but also other nerves and muscles of inspiration (scalenus anticus, sternomastoid, pectorales, serrati, etc.). The stimulation should be interrupted about every two seconds, and expiration should be aided by compressing the thoracic and upper abdominal walls.

The insufflation of air by means of a catheter introduced into the larynx is not to be recommended. If the larynx is partially occluded by a collection of mucus or blood-clots, or by a foreign body, or if there is a spasmodic closure of the glottis, it may be necessary to make an opening into the larynx or the trachea (laryngotomy or tracheotomy) in order to perform artificial respiration. But this necessity seldom arises.

In desperate cases artificial respiration should be kept up from half an hour to an hour, or even longer. Life has been known to be restored after working twenty minutes, even when any measure seemed at first hopeless. There are successful cases on record in which artificial respiration was performed for three to four hours on people who were apparently drowned. Artificial respiration is also the best and surest way of restoring the action of a heart which is failing or has become imperceptible. The direct mechanical effect of compression and movement of the thoracic organs seems to have a stimulating power over the heart's action. The inversion or lowering of the head, accompanied by artificial respiration (Nélaton, Richardson, and others), appears to be particularly advantageous in cases of syncope from chloroform.

Electro-puncture of the Heart.—It has been recommended to stimulate the heart by introducing into its substance a needle charged with an electric current (acupuncture or electro-puncture); but this need only be mentioned to be condemned as too dangerous. Sigmund Mayer has shown that this direct electrical stimulation of the heart by an interrupted or constant current acts as a heart poison. Watson experimented on animals, and found the heart could be punctured without danger, but if the vena cava was entered it was followed by a profuse hæmorrhage into the thoracic cavity. The right ventricle was entered thirty-eight times, the left six times ; the right auricle was entered six times, the vena cava superior three times, the vena cava inferior twice, and the apex twice.

Of the other means which are recommended as restoratives to be used in addition to artificial respiration, if the breathing or heart action stop, I shall mention the following: Sprinkling the face with cold water; slapping the cheeks, forehead, or breast with the hand or with a wet towel; methodical rubbing of the extremities so as to assist the peripheral circulation and stimulate the cutaneous nerves; autotransfusion (see page 52); and the subcutaneous injection of a sodium chloride solution. W. Koch recommends placing the uncovered pole of the induction apparatus, or the copper wire itself, deep in the nasal cavity, and permitting a strong current to act directly on the nasal mucous membrane for ten to twenty seconds.

After a single or repeated stimulation there usually occurs a deep inspiration or expiration, and breathing proceeds without assistance. Should the respiration begin again, and the pulse become regular, suitable stimulants should be administered—olfactory stimulants, stimulating enemas of vinegar, wine mixed with water, or wine alone, subcutaneous injections of camphor or ether, etc.

As a prophylactic measure, particularly in the case of very weak, frightened, or excited individuals, it is wise to administer some alcoholic stimulant before the operation, such as Bordeaux or Massala wine, and Cognac to individuals accustomed to the use of alcohol. In America, particularly, it is customary to give to patients before any important operation some strong alcoholic stimulant, such as brandy, until the patients get into a state of pleasant excitement or partial intoxication. It is believed that the danger of cardiac as well as vasomotor paralysis during the chloroform narcosis can thus be avoided. Moreover, the narcosis under such conditions comes on more quickly.

The other Compounds of Methyl.—The other compounds of methyl—methylether, methylen bichloride, methylenether, and methylal—are now but little used in surgery as anæsthetics. Methylen bichloride alone has found some warm adherents in Spencer Wells, Marshall, Gamgee, and other English surgeons. The drug possesses no real advantage over chloroform,

and only seems to be less liable to cause vomiting. Its disadvantages are its inflammability and expensiveness. Furthermore, its use is not free from danger—in fact it is probably more dangerous than chloroform. Kappeler mentions nine fatal cases. Methylen bichloride is best administered by Junker's apparatus, which is illustrated on page 21.

§ 14. **Ether Narcosis.**—Ether is another much-used anæsthetic which is coming to be employed more and more in the place of chloroform or its compounds. In America, ether narcosis is used almost exclusively, and in England, France, Switzerland, and even Germany, this drug is coming into constantly growing favour.

Ether—sulphuric ether, naphtha, ethylether, $C_4H_{10}O$—is a colourless, easily diffusible liquid, possessing a pleasant odour and burning taste. Ether is very volatile and inflammable, and boils at a temperature of 38° C. Its specific gravity at 15° C. is 0·720. The physiological action of ether is essentially the same as that of chloroform, except that ether less often produces disturbances in the circulatory system, and consequently seldom causes death from syncope, but almost always from paralysis of the respiratory centre. P. Bruns and Holz showed that the inhalation of ether produced an increase in the strength of the pulse, while chloroform, on the other hand, weakens it. Kappeler has collected thirteen cases of death from ether, but the number has increased lately, owing to its more general use. In diseases of the air-passages and lungs and in teething children ether should not be employed.

The manifestations of ether narcosis resemble those of chloroform narcosis, but the action of the drug is not so lasting. During ether narcosis the great amount of saliva secreted is troublesome, stertorous breathing often occurs, and not infrequently a thick white foam issues from the mouth and nose. There occurs, as a result of the dilatation of the cutaneous vessels, an increased warmth, redness, and cyanosis. Finally, mention should be made of the great inflammability of this drug—a circumstance which increases the difficulty of giving it at night or in operations where the galvano- or thermocautery is to be used.

Kappeler relates the case of an eighteen-year-old girl, in Lyons, who was etherised in order to apply the cautery. Suddenly, as the surgeon was about to use the cautery on his patient, the ether vapour ignited, setting fire to the cone filled with ether which was being held over her mouth and nose, and the face of the patient became enveloped in flames. Terrible burns, involving the tissues down to the bone, were the result of this accident, and the surgeon, in his efforts to extinguish the flames, sustained no inconsiderable injuries.

Ether nephritis, though not of frequent occurrence, is a disagreeable after-effect (Goltz). The other consequences of ether narcosis—

the nausea and vomiting—are the same as in chloroform narcosis. Sometimes there have been observed bronchitis, broncho-pneumonia, disturbances of respiration (asphyxia, Cheyne-Stokes breathing), and a collapselike condition, especially after prolonged operations. The collapse from ether is perhaps a result of the cooling off of the surface of the body.

Ether narcosis is certainly much less dangerous than the narcosis of chloroform, and cases of death occur much less often. Juillard (Geneva), Dumont, P. Bruns, Stelzner Fuster, and others, have recently substituted ether for chloroform.

On account of the great volatility of ether, it is advantageous to use an apparatus especially designed for giving it, and Clover's is the one most frequently employed. It consists of three closely connected parts—a metal vessel to hold the ether, a rubber bag, and a mouthpiece. The lower half of the metal vessel is surrounded by a water tank closed by a screw valve, the tank being intended to keep the ether from cooling off too much. I use Dumont's modification of Juillard's mask, consisting of two metal frames placed one over the other and connected by a hinge, the outer one being covered with oilcloth. Between the two frames is placed a piece of cloth or flannel. The mask is large, and covers the whole face. Over it is placed a folded towel to prevent the evaporation of the ether. Czerny's mask is also very useful.

The same precautions are to be observed in etherising as in giving chloroform, and a pure preparation is indispensable. The patient's head should be so placed that the abundant secretion of saliva does not flow into the air-passages. The administration of the ether should be "pushed" more than is customary in the case of chloroform, since it acts more slowly.

About thirty cubic centimetres of ether are usually poured into the mask at once. To keep the patient free from pain, the etherisation demands the constant attention of the person in charge. There is often observed a post-narcotic stage in which the analgesia continues, though consciousness has returned. This also occurs with bromethyl (see page 42). Before etherising it is customary, in England and America, particularly in the case of weak individuals, to give repeated doses of brandy. Beginning some two hours before the narcosis, about thirty grammes of brandy are given every half hour.

Action of Ether on the Laryngeal Muscles.—Semon and Horsley have confirmed by their experiments the observations made by others, namely, that the posterior crico-arytænoid muscles are the first to lose their power of contraction after death, and in cases of organic disease or injury to the centres or to the branches of the motor nerves of the larynx.

In deep ether narcosis there is abduction of the vocal cords; and when the narcosis is slight there is adduction, no matter whether the recurrent laryngeal nerve is divided or not.

Narcosis per Rectum.—Mollière and Iversen have successfully produced ether narcosis by introducing the vapour into the rectum by means of a rubber tube connected with Richardson's ether vapouriser. Mollière also passed into the rectum a rubber tube which was connected with an ether flask standing in water at 50° C. (112° F.), thus causing the ether to boil. Mollière mentions as advantages of rectal anæsthesia the lack of a stage of excitement, the possibility of exactly regulating the amount of ether given, and the convenience of the method in operations on the face.

Rectal etherisation was first used by Pirogoff forty years ago. Recently, Starcke has also investigated the method and has urged its further trial.

It was stated on page 38 that fatal cases are of much less frequent occurrence during ether than during chloroform narcosis. E. Hankel has, with the use of Kappeler's statistics, collected forty-five cases of death from ether and analysed the causes carefully; they include asphyxia, syncope, general paralysis, shock, entrance of pus and ether into the air-passages, etc. Leaving out the cases of actual malpractice, however, death from ether is usually caused by disturbances of respiration.

The other compounds of ethyl have not become established as anæsthetics; amongst them are ethylchloride, ethylbromide, ethylnitrate, ethylidenchloride, ethylaldehyde or aldehyde, Aran's ether, acetic ether, etc.

§ 15. **Laughing-Gas Narcosis.**—Amongst the inorganic compounds, nitrogen monoxide or laughing gas (Davy) is the best anæsthetic. Nitrous oxide, N_2O, is a colourless gas with a slightly sweetish taste and smell. It is made by cautiously heating ammonium nitrate, which breaks up at a temperature of 170° C. into water and nitrous oxide. The anæsthetic action of laughing gas is not unpleasant, and there are almost no disagreeable after-effects; nausea and vomiting scarcely ever occur. But it is not entirely free from danger, though it is much less dangerous than chloroform or ether. Statistics show that out of four to five million cases where it has been used, only fourteen deaths have been recorded (E. H. Hankel). In a few instances it has caused epileptic fits, great excitement, deep cyanosis, and similar phenomena, but in general the drug is relatively free from danger. After making investigations with the spectroscope, Ulbrich came to the conclusion that nitrous oxide formed a chemical combination with the hæmaglobin, and so could become dangerous; but Preyer, Buxton, MacMunn, and Rothmann were unable to confirm these statements of Ulbrich's, as the duration of the narcosis is too short, therefore these authors consider that nitrous oxide is not a dangerous anæsthetic. Still, a narcosis of long duration is not to be recommended. The drug is suitable for short operations, particularly the extraction of teeth, and hence laughing gas is to-day the best anæsthetic for the dentist, and in England and America it is used with

very great frequency. In fifty to sixty seconds the anæsthesia is so complete that minor operations, like the extraction of teeth, can be performed without pain. Recovery from the narcosis is equally prompt, and without unpleasant after-effects. Laughing gas has also been frequently used during parturition, and with good results (Zweifel). The gas is inhaled either pure or mixed with air. For the sake of economy the gas is now stored in a gasometer or rubber bag so arranged that the expired gas can be used over again.

Narcosis with Oxygenated Laughing Gas.—Klikowitsch, Döderlein, Schreiter, and Hillischer have recommended an oxygenated nitrous oxide (nitrous oxide with twenty per cent. oxygen) for narcosis instead of the pure nitrous oxide. It is suited especially for protracted narcosis in which major surgical operations can be performed. The two gases are stored in two separate gasometers and are mixed immediately before inspiration. The apparatus is so arranged that the proportion of the mixture can be altered at any moment.

Narcosis with Oxygenated Laughing Gas and Increased Atmospheric Pressure.—P. Bert has recommended the administration of a mixture of nitrous oxide with fifty per cent. of air under increased atmospheric pressure (two to three atmospheres). With nitrous oxide narcosis conducted under these conditions of increased atmospheric pressure, the operator, his assistants, and the patient must enter a specially prepared room, where the air can be compressed and the patient inhale the nitrous oxide. This atmosphere of compressed air is said not to be very disagreeable for the operator and his assistants. Fontaine has recently constructed a pneumatic cabinet with a capacity of thirty cubic meters, having large windows in the roof and sides, and fitted with wheels. Ventilation is supplied by a valve contrivance. A reservoir with a capacity of three hundred and fifty litres contains the gaseous mixture, which is under a pressure of two or more atmospheres. This mixture, as it is needed, is allowed to enter the sack used in the process of inspiration, the sack being kept beside the operating table. The complexity and expense of P. Bert's method are so great that its general use is as yet impossible. Labbé and Péan have performed a great number of prolonged operations with the use of nitrous oxide under increased atmospheric pressure and with excellent results, and there is some talk in England of constructing operating rooms (to accommodate two hundred spectators) according to P. Bert's directions, for carrying on nitrous-oxide narcosis.

The advantages claimed for nitrous-oxide narcosis with compressed air are: 1. The absence of a stage of excitement. 2. The ease of maintaining for a long time any desired degree of narcosis. 3. The prompt return of consciousness. 4. The absence of vomiting. 5. The complete freedom from danger.

Other Anæsthetics.—The other inorganic compounds which have been tried as anæsthetics, such as nitrogen, carbonic acid, bisulphide of carbon, etc., should be abandoned.

§ 16. **Mixed Narcosis and other Anæsthetics.**—The above-mentioned anæsthetics have been frequently mixed with each other. The Vienna

school recommends a mixture of three parts ether and one part chloroform. Linhart uses a mixture of four parts chloroform and one part absolute alcohol. Billroth favours a mixture of three parts chloroform, one part ether, and one part absolute alcohol. The English Committee on Chloroform has tried three different mixtures: 1. One part chloroform and four parts ether. 2. One part chloroform and two parts ether. 3. One part alcohol, two parts chloroform, and three parts ether.

The first mixture acts like unmixed ether, while the other two are almost the same, and, while inducing a speedy loss of consciousness, interfere less with the functions of the heart than does pure chloroform. I once used almost exclusively a mixture of one hundred parts chloroform, thirty parts ether, and twenty parts absolute alcohol; but at present I employ pure chloroform or ether, giving the latter the preference for children. Different authors have recommended a mixture of oxygen with chloroform, ether, or laughing gas, etc. Many surgeons combine the chloroform and ether narcosis, beginning the narcosis with chloroform and keeping it up with ether. Clover speaks well of the combined use of nitrous oxide and ether, and claims in this way to escape the stage of excitement. Clover uses nitrous oxide first and then carries on the narcosis with ether, and after one to two minutes the patient is in a condition to be operated upon.

Morphine-Chloroform Narcosis.—The morphine-chloroform narcosis—a combination first tried by Nussbaum—is of considerable value. It is especially suitable for alcoholic cases, and for individuals in whom a well-marked stage of excitement is to be expected. One, two, or three centigrammes of acetate of morphine are given in aqueous solution, hypodermically, about ten to twenty minutes before the narcosis is begun, or immediately preceding the latter; afterwards, a second injection may be given during the stage of excitement, or later in the progress of the narcosis, particularly if the operation is protracted. The advantages of a mixed morphine-chloroform narcosis (which I only use on adults) are as follows: The narcosis progresses more quickly and quietly; there is less mental worry; the stage of excitement is shortened, or completely absent; the respiration is more regular, and a smaller amount of chloroform is required. It is possible in this morphine-chloroform narcosis to render the patient insensible to the pain of the operation, while the reflexes are retained, as well as control of the voluntary muscles, and the patient remains in full possession of his senses; he hears and answers any questions which may be put to him. This state of narcosis is very valuable for operations on the face, mouth, pharynx, and nose, as the patient will, when told to, eject

the blood collecting in his mouth, or swallow it, as the reflex excitability of the muscles of the pharynx and palate is not lost. If it is desired to obtain this condition of semi-anæsthesia, one and a half or two centigrammes of acetate of morphine should be injected about ten minutes before the narcosis is begun, after which the patient should be chloroformed till the stage of excitement is reached, and then the amount of chloroform administered should be gradually diminished.

As objections to the combined morphine-chloroform narcosis, both Kocher and I have noticed that the morphine sleep following the operation has a bad influence upon breathing, and permits the inhalation of foreign matter with a resulting aspiration-pneumonia.

Instead of injecting morphine subcutaneously, two to four grammes of chloral hydrate can be given by mouth some time before the operation. This chloral-chloroform narcosis resembles quite closely the morphine-chloroform narcosis. According to Kappeler, it is better to give ether combined with a previous administration of chloral hydrate than with a subcutaneous injection of morphine.

Oré, Deneppe, and Van Wetter have repeatedly produced anæsthesia by injecting chloral hydrate into a vein, but this is entirely too dangerous to be made use of.

Other Anæsthetics.—*Acetal.*—Recently Von Mering has tested the anæsthetic powers of acetal, and particularly dimethylacetal and diethylacetal. He strongly recommends a mixture consisting of two volumes of dimethylacetal and one volume of chloroform, as being less dangerous than chloroforms since it has less of the paralysing effect on the heart's action. Lücke states that the narcosis induced by dimethylacetal and chloroform has no marked stage of excitement, and only exceptionally causes vomiting.

Bromethyl.—Chisholm, Pauschinger, Szuman, Sternfeld, Scheps, Eschricht, Gilles, Wilcox, and others, have recommended the inhalation of bromethyl as an excellent anæsthetic for short operations—extraction of teeth, etc. Wiedemann has used the drug with success in confinement cases. If there is tuberculosis, or disease of the heart or kidneys, the drug is as dangerous as chloroform. Cases of death have been reported here and there, which, according to Gilles, are principally due to the use of an impure preparation, and of too large a dose, and to confusing it with bromethylene. E. Hankel mentions nine fatal cases.

Bromethyl (ethyl bromate), bromate of ether, C_2H_5Br, is a colourless liquid smelling like ether and having a neutral reaction. It is neither inflammable nor explosive, but evaporates very rapidly when exposed to the air. When pure bromethyl is poured on the hands it immediately evaporates without leaving a greasy feeling. If this is not the case the bromethyl is not pure, and should not be used for narcosis. The method of conducting the narcosis with this drug is the same as with ether and chloroform, and I have used it with success in short operations—extraction of teeth, etc.

Bromethyl acts better when access of air is prevented as far as possible,

by laying a piece of folded cloth or compress over the inhalation mask, or, still better, by using the Juillard-Dumont ether mask with its oilcloth cover. In children ten to fifteen grammes, and in adults ten to thirty grammes are necessary to produce the narcosis, which usually comes on in about one half to one and a half minutes and lasts one and a half to three minutes, and is seldom followed by disagreeable after-effects, though I have several times seen vomiting. During the next two or three days the breath has an unpleasant smell of garlic.

Bromethylene should be entirely rejected. Szuman observed a fatal instance of its use in a man twenty-seven years old, who was given by mistake thirty grammes of bromethylene instead of bromethyl.

Bromoform.—Von Horoch has studied the anæsthetic effect of bromoform, but the results obtained do not, as yet, seem to justify its use in surgery.

Pental.—Amylene, which has been recently given the name of pental (C_5H_{10}) by C. A. Kahlbaum, has been much used for narcosis in short operations. The method of its administration is the same as that of chloroform, and anæsthesia occurs in from fifty to ninety seconds. It has no influence on the heart and respiration, and the patient regains consciousness in three or four minutes, while sensation remains lost for several minutes longer. Pental is inflammable, like ether. It appears not to be free from danger, as Gurlt reports one fatal case, and Schede and Breuer have each observed one bad case of syncope and another of asphyxia.

Narcosis resulting from Irritation of the Laryngeal Mucous Membrane.—Brown-Séquard made some very interesting investigations which show that general anæsthesia may follow irritation of the laryngeal mucous membrane with carbonic acid and chloroform, and he amputated the thigh of a rabbit in this way without pain. The irritation of the laryngeal mucous membrane is the essential thing; after division of the superior laryngeal nerve anæsthesia does not occur. If the superior laryngeal nerve on only one side is cut, and the carbonic acid or chloroform is then applied, there results simply a slight diminution of sensation on this side, while upon the other there is a condition of complete or partial anæsthesia; on one side a toe could be amputated without the least pain, but on the other side the operation caused the most violent manifestations of pain.

§ 17. **Local Anæsthesia.**—For producing local anæsthesia of a particular part of the body, the methods are: compression, cold, electricity with or without the addition of a narcotic, and, above all, the local application of certain drugs. Frequently, in former times, the vessels and nerves of an extremity were tightly compressed by a tourniquet, which caused a local though certainly insufficient anæsthesia. Cold is also a good local anæsthetic. James Arnott was the first to employ a freezing mixture of ice and salt; but since 1866 Richardson's ether spray has come into much more general use, and is far more convenient.

The ether is sprayed over some particular spot on the skin for one or two minutes, causing the skin to become first red, then, as the evap-

oration of the ether produces cold (—15° C.), it becomes white, parchmentlike, and without feeling. But the loss of sensation is principally limited to the skin. This method is suitable for small operations—opening abscesses, puncturing cysts, and for operations on the extremities after the latter have been tied off with a tight elastic tourniquet. By the use of a fan the anæsthesia is hastened, and by interrupting the circulation the freezing of the tissues is favoured. Robbin's anæsthetic ether, which is practically methylene bichloride, works better than the ordinary sulphuric ether. I am perfectly satisfied with the anæsthesia produced by the ether spray, assisted by Esmarch's constriction of the extremity, and I prefer it to the subcutaneous injection of cocaine. Attempts have been made to perform in this way even major operations, such as ovariotomy (Spencer Wells), Cæsarean section (Richardson, Greenhalgh), joint resections (Szymanowski), excision of the breast, etc., but these instances are rare.

Redard recommends chlorethyl as a substitute for ether in the freezing method; but it cannot very well be used on an open wound, as it is excessively painful.

A spray of methylene bichloride is used in the same way as the ether spray, especially in France.

At present we have in cocaine a most excellent local anæsthetic, which was first used in ophthalmology by Koller. The drug acts especially well on mucous membranes, and consequently is very generally used, and with the best results, in operations on the eye, nose, mouth, pharynx, larynx, vagina, and uterus. It is applied in solution in the form of injections or instillations, or it is painted over the particular mucous surface with a brush, or it can be made into an ointment. The solution of cocaine is not permanent, as it is very susceptible to the action of fungi. It should therefore be kept only in small quantities, with a little bichloride or carbolic added to it. It has a better anæsthetic action if the freshly prepared solution is neutralised by the addition of a little carbonate of sodium (A. Bignon). A five- to twenty-per-cent. aqueous solution is the best for operations on mucous membranes. This is dropped into the conjunctiva or painted over the other mucous membranes. It is also good for small operations involving the skin—incision, removal of tumours, exarticulation of fingers, etc.—five, ten, or fifteen milligrammes being injected into and under the skin with a hypodermic needle. I use for this purpose a weak solution (one per cent.), and inject enough to fill the syringe from one to three times. After the injection one should wait three or four minutes, as anæsthesia takes place in about that time, and lasts ten, fifteen, or twenty minutes.

By using, at the same time, artificial anæmia, or by a preliminary

application of the ether spray, the anæsthetic action of cocaine is materially assisted. This method is not adapted for major operations. Cocaine is not free from danger, and should be administered with great care, as numerous cases of poisoning have been observed during its hypodermic use, though hitherto they have terminated, as a rule, favourably. These unpleasant effects are vertigo, excitement, loss of consciousness, cramps, pallor of the face accompanied by a small, rapid pulse, etc. According to Reclus, there have been, so far, fourteen fatal cases from the use of cocaine, but the real number is undoubtedly much greater. Death was generally caused by injecting too large an amount of a concentrated solution, as in the majority of the cases more than twenty-two centigrammes of cocaine were given. Consequently only a one- to two-per-cent. solution should be employed for hypodermic use. Care must be used in dropping it into the conjunctival sac, especially in children.

Wölfler uses, as a maximum dose for injection about the head, two hundredths of a gramme; for the extremities, five hundredths of a gramme. The best antidote for cocaine poisoning is amyl nitrite, which should be given just as soon as there is any symptom of cerebral anæmia (Feinberg).

Cocaine in Conjunction with the Galvanic Current.—Wagner and Herzog have anæsthetised the unbroken skin with cocaine in conjunction with the galvanic current. The anode, previously dipped in a cocaine solution, is placed upon the skin a certain distance from the cathode, and, after the current has been turned on, the portion of the skin lying between the electrodes becomes anæsthetised. The strength of the current was two to four milliampères. The method depends upon the cataphoric action of the current in moving fluids from the anode to the cathode.

Cocaine with Ethylchloride.—E. Nagy has good results from the use of cocaine in combination with ethylchloride for the extraction of teeth (one third to one half a syringeful of a freshly prepared two-per-cent. solution of cocaine). The gum is sprayed with the ethylchloride for about a minute after the injection of cocaine, until a thick layer of white crystals forms.

Other Anæsthetics possessing a Local Action.—The local application of chloroform, opium, saponin, amylene, carbon bisulphide, etc., or the use of the constant or induced current in combination with chloroform, tincture of aconite, the alcoholic extract of aconite, etc., have all been found to be of little value. On the other hand, I have had good success with menthol (in combination with lanolin or olive oil). Menthol is not a dangerous drug, and a whole hypodermic needleful of a ten- to twenty-per-cent. solution of menthol in olive oil can be injected into and under the skin. The ether spray may be combined with it. The

local application of a mixture of equal parts of menthol and lanolin has also been found efficacious.

As a substitute for cocaine, Claiborne has recommended stenocarpin in a two-per-cent. solution. It is a very expensive alkaloid.

Erythrophlæine has been used as an anæsthetic, but is of little value. Drumin, an alkaloid from euphorbia, has also been tried. Vidal, Labbé, and St. Germain have used chloral-methyl for local anæsthesia with good results. It acts not only upon the skin but also upon the deeper tissues (muscles and bone). Chloral-methyl has the advantage over the ether spray is that it can be used in operations in which the thermo-cautery is employed.

CHAPTER III.

THE PREVENTION OF LOSS OF BLOOD DURING AN OPERATION.—ESMARCH'S ARTIFICIAL ISCHÆMIA.

The prevention of loss of blood in all operations.—Different methods: Digital compression of the main artery; tourniquets; ligation, or "umstechung," tearing, tying-off, or clamping of adhesions or of blood-vessels before they are divided.—Esmarch's artificial ischæmia in operations on the extremities: its technique; its advantages and disadvantages.—Modifications of Esmarch's method.—The application of the method to various parts of the body.—Historical.

§ 18. **The Prevention of Loss of Blood during an Operation.**—In all operations we must bear in mind the necessity of making the loss of blood as small as possible, particularly in the case of weak or anæmic individuals, in children less than a year old, and in the aged. If this rule is not taken to heart many a patient will perish simply from loss of blood. It is a precious fluid.

The modern surgeon has many ways of saving blood during an operation. Frequently the artery supplying the part in question is ligated before the operation is begun, as, for instance, both lingual arteries in removal of a cancerous tongue; or the artery is compressed by the finger only while the operation lasts (digital compression); again, in some cases, the vessel may be secured by a suture passed through the skin and under the vessel (percutaneous ligation *en masse*).

In the extirpation of new growths and tumours connected to the surrounding parts by vascular and more or less strong adhesions, the vessels, or the vascular adhesions, are seized by self-locking pincers or artery clamps, and the vessels, or vascular strips of tissue, after being secured by two clamps, or a double ligature of silk or catgut, are divided between them.

This procedure is much facilitated by tearing through the weak, non-vascular attachments, which yield readily to the pressure of the finger, while the stronger and more vascular parts resist, and can be felt and more readily recognised.

Lacerated wounds bleed less than incised ones. If a large vessel is wounded the bleeding from it is at once stopped by the pressure of the finger, and the vessel is then seized by an artery clamp and divided be-

tween a double ligature, one of which closes the central and the other the peripheral open end of the vessel. In other cases, to prevent loss of blood, the cautery iron or galvano-cautery is used, etc. The technique of this method is mentioned later (§ 25).

§ 19. **Esmarch's Artificial Ischæmia.**—The bloodless method of operating on the extremities has been perfected by the ingenuity of Esmarch. In removing an extremity by Esmarch's method, not only do we save the blood in the limb to be amputated, but also, during the operation, bleeding is almost entirely prevented by the elastic constriction of the limb previously made anæmic. The so-called tourniquet (Fig. 25) used

Fig. 25.—Petit's screw tourniquet.

Fig. 26.—Digital compression of the femoral artery.

Fig. 27.—Digital compression of the brachial artery.

to be used to check the flow of blood during amputations, or the same end was attained by compressing the main artery of the part with the fingers (digital compression). (Figs. 26, 27.)

Tourniquets.—The tourniquet illustrated in Fig. 25 is the screw tourniquet of J. L. Petit (1718). The encircling band is fitted with a pad, and is tightened and held fast by the buckle at the other end of the band. By turning the screw the pressure of the tourniquet can be made as great as desired. The apparatus is applied in such a way that the pad presses directly upon the artery. Besides this there is the *stick tourniquet* (Morell), consisting of an encircling band or a piece of cord or cloth, to fasten around the extremity, and a staff or stick which is passed under the encircling band. By twisting the stick the constriction of the limb can be made as tight as desired. A pad of cloth or a roller bandage can be placed directly over the artery.

There is also the buckle tourniquet of Assalini, and the bow tourniquet of Dupuytren.

At the present time, for rendering operations on the extremities bloodless we use Esmarch's very simple and efficacious method, which

consists in tying off the member after it has first been emptied of blood. The old-fashioned tourniquets and digital compression have been abandoned for this.

Suppose, for instance, that we wish to perform an amputation of the leg. After the leg has been properly disinfected and shaved, it is first elevated and then wrapped in an elastic bandage drawn moderately tight, from the toes upward as far as the lower third of the thigh. The end of the bandage is then held by an assistant, or after the last turn the roll is tucked under the immediately preceding turn. The bandage should have been previously disinfected by immersion in a solution of one tenth per cent. bichloride or of three to four per cent. carbolic. To avoid forcing into the lymph channels any noxious materials, such as tumour germs or pus, etc., the diseased part should not be covered by the wrappings, but carefully avoided; or, better still, the elastic bandage should in such instances not be used at all.

Finally, Esmarch's rubber tourniquet is wound moderately tight around the limb at the upper termination of the elastic bandage, and the latter is removed. Fig. 28 illustrates the usual form of Esmarch's elastic tourniquet, with a chain and hook for fastening it.

Fig. 28.—Esmarch's rubber tubing for producing artificial ischæmia.

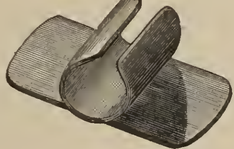


Fig. 29.—Clamp for the rubber tubing used for producing artificial ischæmia.

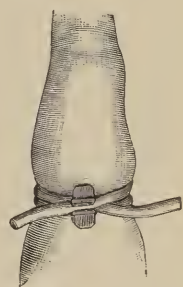


Fig. 30.—Fixation of Esmarch's rubber tubing by means of the clamp.

Another way of securing the tourniquet is illustrated in Figs. 29 and 30. The two ends of the rubber tube are inserted in a so-called "tube clamp," which consists of a half-open brass ring fastened to a plate. The ends of the tube are well stretched and forced into the slot, and when relaxed the ends are held tightly pressed together (Fig. 30). Thus the extremity is emptied of blood up to the lower third of the thigh, and the leg can be amputated as on the cadaver.

At the conclusion of the amputation the principal arteries and veins are clamped and tied. This is quickly done, as the vessels can be easily seen in the bloodless stump. The larger muscular branches of the arteries will be found at the point where the connective-tissue sheaths

which envelop the different bundles of muscles cross each other. When all the visible vessels have been secured in the bloodless stump the latter is elevated, and its surface compressed with two to three aseptic sponges or compresses, while an assistant slowly loosens the Esmarch tourniquet, but is ever on the alert to tighten it again if bleeding should occur at any point. After removal of the tourniquet the hitherto apparently dead extremity becomes bright red. At the same time, unless the stump is elevated perpendicularly and the wound compressed for a couple of minutes, there almost always follows considerable oozing, because the pressure of the elastic tourniquet produces a temporary vasomotor paralysis which prevents the smaller, unsecured vessels from contracting and closing spontaneously.

When Esmarch's method first came into general use this oozing was thought by many surgeons to be such a serious matter as almost to outweigh the advantages of the method, and others held that the loss of blood during the oozing which followed was greater than in the case of the old methods. Ice-water irrigations, the application of the electric current, injections of ergot into the tissues around the wound, etc., were all practiced to prevent this oozing.

I have always been perfectly satisfied with elevating the stump and making pressure on the wound for a couple of minutes with sponges or compresses, and after doing this I have never seen any subsequent oozing worth mentioning, and the patient loses really only a few drops of blood.

Esmarch recommended that drains be put in place, and the wound sutured and dressed antiseptically before removing the elastic tourniquet. This can be done in suitable cases—for instance, in necrosis operations or extirpation of tumours. I never adopt it in amputations and resections, but always check the bleeding first. Whichever plan is adopted, the extremity which has been operated upon should, after the dressings have been applied, be invariably placed in an elevated position for the next twenty-four hours, as by this means the oozing will be minimised.

This elevation of the stump has also an antiphlogistic and analgesic effect, and therefore can be used with great advantage in various forms of inflammatory processes in the extremities. When the extremities are elevated there is regularly a diminution in the height of their temperature. According to Meule, for an elevation lasting sixty minutes, the maximum diminution is 7·2° C. (12·9° F.), the minimum 2° C. (3.6° F.). Furthermore, the blood pressure is lessened, and the frequency of the pulse averages a decrease of nine beats to the minute. Upon this also depends the hæmostatic power of elevation.

In many instances, as has been mentioned, the elastic bandage can be only partially applied to the extremity before encircling the latter with the elastic tourniquet; sometimes the bandage cannot be used at all. The bandage can be carried to within a short distance of circumscribed abscesses or very soft tumours, but if there is a spreading suppuration or phlegmonous inflammation the Esmarch bandage should not be used, as the infectious matter would be forced into the meshes of the connective tissue and into the lymph channels. If it has been decided not to use the Esmarch bandage, it will be sufficient to hold the extremity vertical for a couple of minutes and then apply the rubber tourniquet. The elevation of the limb should be accompanied by a gentle rubbing of the skin from the periphery towards the centre to lessen the amount of blood contained in the limb. Lister for years has practiced vertical elevation of the extremity without wrapping it in Esmarch's elastic bandage, and it is sufficient for many cases. At present I usually avoid the elastic bandage, and use the elastic tourniquet after elevation of the limb.

The advantages of Esmarch's method consist in the actual saving of blood and in the possibility of operating in a dry wound without the need of sponges. Moreover, fewer assistants are required, and everything can be plainly seen—a matter of much importance in searching for a small foreign body, like a needle point, or for a wound in a blood-vessel. Furthermore, Esmarch's elastic tube tourniquet can be applied to any part of the extremities, which was not the case with the old-fashioned appliances.

The method has really no serious disadvantages. It has been shown how easy it is to stop the oozing which follows removal of the elastic tourniquet and which has been found fault with by so many surgeons, and I do not yet consider it proved that the edges of wounds, for instance, in amputations, become more often necrotic after using Esmarch's method (König). Sometimes there has been observed a paresis of the nerve trunks of shorter or longer duration, especially after tight constriction of the arm, and in exceptional cases cutaneous flaps have died from want of nourishment. But these mishaps are not to be ascribed to the method, but to its unskilful application—i. e., to too much compression.

Jul. Wolff recommends that Esmarch's procedure be carried out in the following way: After performing an amputation, only the main vessels are to be ligated; then a temporary antiseptic dressing is applied, the limb is raised, and the elastic tourniquet is removed, after which one waits twenty minutes; next the temporary dressing is removed, the wound sutured, and a permanent antiseptic dressing is applied, but without exerting great pressure,

and the stump is placed in an elevated position. But I have found it much simpler and equally efficient to compress the amputation stump with aseptic sponges for about two minutes after removing the Esmarch elastic tourniquet. This pressure prevents the oozing if all the vessels in sight have been ligated before the removal of the tourniquet.

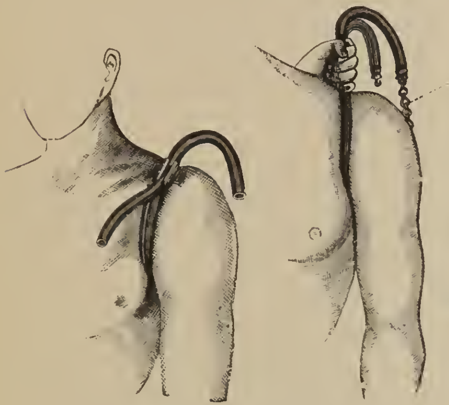
The Increased Power of Absorption possessed by the Tissues after Removal of the Elastic Tourniquet.—Wölfler experimented on dogs with potassium ferrocyanide, cyanide of potash, strychnine, etc., to determine whether, in a limb rendered anæmic by Esmarch's method, absorption occurs up to the point of application of the rubber tubing, and how the absorption is affected by removal of the constriction. It appeared that while the elastic tourniquet remained in place no absorption occurred, but that after it was removed absorption was very much accelerated. Therefore Wölfler recommends that the constriction be maintained until the wound has been dressed antiseptically and elevated. All moistening of the wound with such poisonous substances as carbolic acid, bichloride of mercury, and the like, should be done before the removal of the elastic tourniquet.

Autotransfusion.—After great losses of blood, which endanger life, Esmarch's bandage may be applied to the extremities in order to force the blood in the latter towards the heart, and so avert a threatened heart failure, or cerebral anæmia (so-called autotransfusion).

For how long a time can Esmarch's constriction be kept up with impunity?—At present this question cannot be satisfactorily answered. Esmarch has maintained his artificial anæmia on human limbs for two hours and a quarter without doing any damage. The results of animal experimentation cannot be applied to man, and therefore I shall omit a discussion of the same.

The following is a brief summary of the technique for applying Esmarch's constriction to particular parts of the body. The method of using Esmarch's elastic tourniquet on the shoulder for high amputation of the arm, or for removal of the arm at the shoulder joint, is illustrated in Fig. 31, *a* and *b*. The Esmarch elastic tourniquet cannot be used for exarticulation of the arm—e. g., for a large tumour—because here the artery would be compressed against the head of the humerus, and as soon as the latter was freed from the joint the tourniquet would be useless. Therefore it is better in such a case either to ligate the subclavian artery first and then proceed with the exarticulation, or to perform a high amputation of the arm, using Esmarch's constricting rubber tube, then ligate the vessels in the stump, and finally remove the remaining portion of the humerus subperiosteally. It is manifestly not wise to carry Esmarch's elastic tourniquet around the thorax in the form of a shoulder spica, as the thorax would be compressed during the narcosis. The manner of applying the elastic tourniquet in the region of the hip, for amputation of the thigh, is illustrated in Fig. 32.

The pressure on the femoral artery can be increased by placing a cloth pad or roller bandage beneath the elastic tube over the artery. For

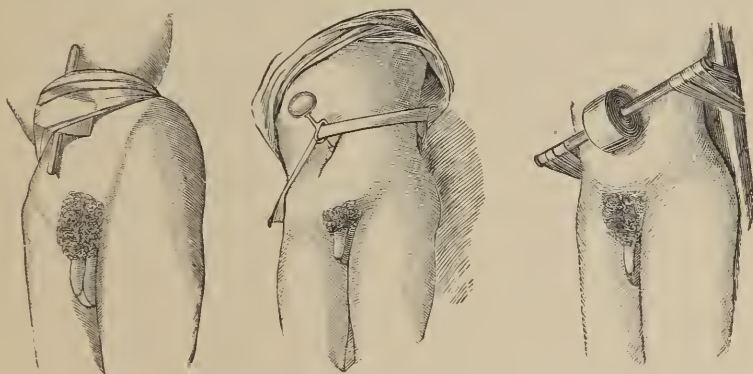


a b

FIG. 31.—Esmarch's tubing applied at the shoulder.

FIG. 32.—Application of Esmarch's rubber tubing about the hip.

amputation of the hip joint, Esmarch recommends compression of the aorta after having previously emptied the intestines (Fig. 33, *a*, *b*, *c*). The following plan (Volkmann's), is better: after applying the rubber bandage tightly up to the inguinal region, the elastic tourniquet is carried from the femora-scrotal commissure in the direction of Poupart's liga-



a b c

FIG. 33.—Compression of the aorta (Esmarch).

ment obliquely outward to the semilunar notch of the ilium between its two anterior spines. During the operation the tube is held in the hands of an assistant, or, better still, it is secured in position by three pieces of bandage tied around it and drawn upward to prevent it slipping down after division of the muscles. Esmarch's artificial ischæmia, combined

with local anæsthesia, is excellent for small operations on the fingers and toes. In operations on the male genitals Esmarch winds a small rubber tube around the base of the scrotum and penis, and, crossing its ends over the mons veneris, he carries them around behind and ties them together over the sacrum. But I do not consider the tourniquet necessary, particularly in amputation of the penis, where compression of the part with the fingers is sufficient.

Von Langenbeck has also used Esmarch's method in operations on the scalp. The head is first wrapped in a gauze bandage, according to the rules for applying the "Mitra Hippocratis" (see § 50, Bandaging); then the rubber bandage is passed around the forehead and occiput and the gauze bandage cut off.

History of Artificial Anæmia.—Constriction of an extremity above the point of amputation was much used long before the invention of the tourniquet by Morell and J. L. Petit, and Ambroise Paré practiced the method in the sixteenth century. Even artificial anæmia is said to have been used here and there, though never so perfectly as by Esmarch. As Albert points out, an English surgeon named Clover, in 1852, before amputating a thigh, bandaged the extremity from the toes to the perinæum, and encircled the limb with a tourniquet above the bandage.

Chassaignac, in 1856, employed a rubber tube to constrict an extremity for hæmorrhage. Constriction of an extremity with a rubber tube or a bandage, combined with elevation of the extremity, had been repeatedly practiced (Lister, Silvestri, Guyon) before Esmarch brought his method into general use. Grandesso Silvestri appears to have been the first to envelop a limb with an elastic bandage, and, instead of a tourniquet, to have used an elastic tube. But little notice was taken of Silvestri's proposition, and then Esmarch, without knowing what Silvestri had done, continued the same method. The honour of bringing artificial ischæmia to its present perfection is certainly due to Esmarch.

CHAPTER IV.

GENERAL RULES FOR PERFORMING AN ASEPTIC OPERATION AND FOR THE AFTER-TREATMENT OF THE PATIENT.

a. Behaviour of the surgeon during the operation. *b.* Experienced assistance. *c.* Close observance of antiseptic principles. *d.* Asepsis and antisepsis. *e.* Accidents during the operation: (1) Syncope; (2) spasm; (3) hæmorrhage. *f.* Operations on "bleeders." *g.* Death from entrance of air into the veins. *h.* Death from other causes. *i.* Supplement: (1) After-treatment of operative cases; (2) the most important causes of death after operation.

§ 20. **Performance of an Aseptic Operation.**—After the above-mentioned preparations for an aseptic operation have been made, and the patient has been anæsthetised, every operation should be performed quickly, without hesitation, and with the most scrupulous regard to antiseptic precautions. It is not of so much importance now as it was before the introduction of anæsthesia to perform an operation with great rapidity in order to spare the patient pain. But even at the present time we perform operations as quickly as possible, because we know that an operation by lasting for too long a time may prove fatal to the patient. Especially is this true in operations in the peritoneal cavity, which may prove fatal shortly after the operation because of the long-continued loss of body heat (Wegner). The most important conditions for rapid and safe operating are: a careful examination of the patient before operation; a certain diagnosis; accurate anatomical knowledge; and a natural manual dexterity. A sharp knife and proper instruments scrupulously clean are, of course, indispensable.

As we are fully conversant of the fact that all wound diseases are the result of infection by bacteria, and that the life of our patient may be placed in great danger if the bacteria enter the wound, we must always observe the strictest asepsis; no unclean finger, no instrument which has not been previously disinfected, must come in contact with the wound. The hands and clothing of the operator and his assistants, the instruments, sponges, or gauze pads, the field of operation, etc., are sterilised after the method described in § 6, and everything around the area to be operated upon is covered with aseptic compresses

or towels. Beside the operator and his assistants there should be suitable basins for holding clean disinfecting solutions, especially three-per-cent. carbolic or 1 to 1,000–5,000 bichloride. Particular care must be taken that the wound is not contaminated directly or indirectly by any spectator's hands which have not been disinfected—for instance, by allowing him to pass instruments, sponges, etc. Most carefully sterilised sponges or pads are used to keep the wound dry, but they should bring nothing into the wound from the surface surrounding it. For operating upon the cavities in the body—e. g., the mouth, vagina, etc.—"clamp sponges" are required.

An excellent pad or sponge holder is illustrated in Fig. 34. By pushing up the ring the jaws are closed, and so firmly hold the sponge or pad. The use of too concentrated antiseptic solutions should be avoided, for they may cause dangerous or even fatal poisoning. We should make it our aim to irritate the wound as little as possible.

Fig. 34. Sponge holder.

The beginner must learn gradually, by experience, all that I have mentioned; what he can learn from books is not sufficient. When the operation is finished, the fate of the patient is practically already settled.

Lister's original antiseptic spray of three-per-cent. carbolic acid, etc., is at present seldom used during operations; and the once popular antiseptic irrigation has been pretty generally abandoned, and rightly, as it is unnecessary in a fresh, uninfected operation wound made by perfectly disinfected instruments and aseptic hands.

§ 21. **The Accidents during an Operation.**—The accidents which are liable to occur during an operation can be only briefly mentioned here. We naturally leave out of account all the numerous unpleasant things which may be caused by the operator's error in diagnosis, his lack of skill and judgment, etc. The reader is referred to my text-book on special surgery for many common accidents peculiar to certain operations—such as the disturbances which may be caused by operations on the mouth, air passages, and thoracic and peritoneal cavities.

Mention has been made on pages 33 and 34 of the accidents occurring during narcosis. I will describe the other unfortunate occurrences briefly as follows:

Syncope.—Syncope occasionally takes place, especially in weak and anæmic individuals, during small operations performed without chloroform. It either comes on suddenly, without warning, or it is preceded by a feeling of anxiety, or a sinking feeling about the pit of the stom-

ach, or nausea, etc. The face becomes deadly pale and covered with a cold sweat, consciousness is lost, and the patient falls to the floor if standing, or drops to one side if he is sitting in a chair. Sudden death has been known to occur in this way, as mentioned on page 28. During the swoon the sense of pain is lost.

Cramps.—Hysterical or alcoholic individuals sometimes have convulsions either with or without the syncope. If the cause of the syncope is purely nervous the patient soon recovers, usually after a few seconds, and seldom requires longer than two or three minutes. If excessive loss of blood is the cause of the syncope the prognosis is of course less favourable. The nature and treatment of this form of syncope will be taken up under the subject of Wounds.

The treatment of the nervous syncope, if I may call it such, consists in placing the patient in the horizontal position, sprinkling the face with cold water, chafing and rubbing the body and soles of the feet with wet cloths, giving stimulants, camphor, wine, ammonia, also plenty of fresh air, etc.

Bleeding.—The dangers which arise from bleeding during an operation are slight, as the capable and careful surgeon is able to control it in a great many ways. The treatment of bleeding is discussed in §§ 27–30.

An operation may be complicated in a very dangerous way—if it is undertaken on an individual of the class of so-called "bleeders."

The "Bleeder Disease," or Hæmophilia.—The term "bleeder disease," or hæmophilia, is understood to mean a constitutional anomaly, almost always congenital, which is characterised by a very marked predisposition to bleeding spontaneously or as the result of some slight traumatism.

Hæmophilia is generally an inherited disease, and occurs in so-called bleeder families, in which it is transmitted through many generations, afflicting the members in both the direct and indirect lines of descent. Lassen has investigated three generations of a bleeder family of one hundred members which took its origin from healthy parents; seventeen of this family were bleeders, and nine died from excessive loss of blood. The disease appears to be more common in the male sex—according to König, in the proportion of one woman to thirteen men. Furthermore, it is a fact that hæmophilia is transmitted chiefly through the female members of the bleeder family who do not themselves suffer from the disease and who marry healthy men. Moreover, the children of a male hæmophiliac are usually free from the disease. In only exceptional cases this anomaly appears not to be congenital but to develop slowly after birth.

The pathology of hæmophilia is still but little understood. The cause of the disease has been ascribed to an abnormal thinness of the walls of the vessels, leading to their easy rupture; to their possessing too slight a power of contraction, or rather to a deficiency in the muscular coat of the arteries;

to an abnormal blood pressure due to too small a calibre in the main arterial trunks; and, finally, to an abnormality in the composition of the blood, manifested by imperfect coagulation. But there is no proof that any of these causes actually produce hæmophilia, and the microscopical and chemical examination of the blood has hitherto warranted no conclusion as to the etiology of the disease. The blood usually coagulates normally, though I can affirm, in respect to one case at least, that the blood coagulated rather slowly and imperfectly. The patient died from the constantly recurring loss of blood from a wound of the forearm. I regret that I did not make a careful examination of the blood in this case, but I believe that the blood, or rather its power of coagulation, is not normal in hæmophilia.

We know that in pronounced leucæmia, a disease of the blood characterised by the presence of an excess of white blood-corpuscles, severe or unrestrainable hæmorrhage may occur. For this reason surgeons hesitate before removing an enlarged spleen in leucæmia; almost all the patients hitherto operated upon have died from hæmorrhage. The walls of the blood-vessels in a case of hæmophilia probably do not possess the normal degree of strength, and consequently are easily ruptured by the slightest traumatism, or even without any known cause.

Thiersch also thinks that the cause of hæmophilia lies in an analomous condition of the walls of the blood-vessels and in the way the new vessels are formed in the healing of the wound. Thiersch correctly emphasises the fact that the hæmorrhage always begins anew when the scab or thrombus is disturbed, and therefore he believes that each time the scab or thrombus comes away the newly-formed vessels have not sufficiently strong walls to withstand the pressure of the blood; the cells or the intercellular cement substance, or both, are usually at fault.

As to the symptomatology of hæmophilia, the hæmorrhages sometimes begin immediately after birth—for instance, as an umbilical hæmorrhage—or they accompany circumcision in Jewish boys, but usually they make their appearance later, at the time of dentition, of shedding the milk teeth, or at the age of puberty; in other words, at periods of life when traumatisms are of more frequent occurrence.

The hæmorrhages, usually parenchymatous in nature, take their origin from traumatisms even of the most insignificant kind. Spontaneous hæmorrhages have been observed without any apparent cause; for instance, in and under the skin and mucous membranes, or from the stomach, intestine, and genito-urinary tract. But these hæmorrhages may be caused by slight injuries of an unknown nature. At any rate, parenchymatous hæmorrhages in internal organs which are thoroughly protected almost never occur.

The traumatisms which produce bleeding in hæmophilia are often of the most insignificant kind; for instance, a trifling pressure on some part of the skin will occasion bleeding into and beneath this area, brushing the teeth will cause the gums to bleed, and blowing the nose is often followed by a prolonged nosebleed. Of especial interest are the hæmorrhages into the joints, producing a peculiar multiple joint disorder (see Diseases of Joints). The bite of a leech or an insect, the prick of a needle, are not uncommonly followed by a remarkably profuse hæmorrhage. Fatal hæmorrhage has been observed to follow the extraction of a tooth, and when open wounds

are made and operations are undertaken the result can be imagined. In a pronounced case of hæmophilia every method of hæmostasis may be tried in vain and the patient will die of hæmorrhage. The bleeding may appear to be stopped, but it will recur again and again. Such a state may go on for days, weeks, and even months, but it generally requires only a few days to terminate life.

Usually, bleeders seem to possess a remarkable power of withstanding the loss of blood, and not infrequently recover completely from very large hæmorrhages. One patient of Coates's lost twelve kilogrammes of blood in eleven days. As the subject of hæmophilia grows older the intensity of his disease seems to diminish, and in a few instances has disappeared entirely.

The prognosis of hæmophilia depends upon the severity of the disease and the number and kind of traumatisms the individual may be subject to. Many sad cases go to show that patients with marked hæmophilia often do not get beyond the age of boyhood, but die quite young from some trifling wound or some necessary operation, or they waste away with marked anæmia, which is gradually produced by the constantly recurring losses of blood resulting from the slightest mechanical injury. As they get on in years the prognosis improves, and the disease, when rudimentary in character, may disappear altogether.

Treatment of Hæmophilia.—In the case of children who come from bleeder families or have a marked tendency to bleeding, prophylaxis is very important. Every means should be taken to improve their general condition by good food and air, by frequent baths, by a careful toughening of the body, etc., and in this way the disposition to bleeding may perhaps be checked, or at least diminished. The rest of the prophylactic treatment consists in protecting the patient, as far as possible, from every kind of traumatism which may give rise to bleeding. Any trifling mechanical or operative procedure—for instance, vaccination—should be conducted with the utmost caution; operations should only be performed in case of the most extreme urgency. Not infrequently bleeders have died of hæmorrhage after an operation, because there was no previous knowledge of their fatal peculiarity.

The process of healing in bleeders is accompanied by peculiar difficulties, which are illustrated by an experience of Thiersch's, who removed an encysted tumour from the face of a bleeder at his urgent request. The wound took six weeks to heal, and the patient came near dying from the complications. Thiersch recommends, from his experience, that the wound be not sutured, and that compression dressings be discarded.

Hæmorrhage in bleeders is checked by ligation of the bleeding vessels, and when necessary by the application of a solution of perchloride of iron, or the actual cautery, generally in the shape of the Paquelin instrument. It has been mentioned that bleeding is especially apt to occur when the eschar or thrombus comes away, and therefore they should be kept from being disturbed as long as possible. Thiersch, in his case, allowed the wound to fill with a blood clot and surrounded it with a wall of compresses impregnated with ten per cent. of salicylic acid, and then wrapped the whole thing in a thick layer of carbolised jute contained in sterilised gauze without applying any pressure. In this way he avoided all pressure, and also prevented the clot from becoming prematurely loosened. On the thirty-eighth

day the clot came away and the entire surface of the wound was skinned over. The internal treatment of hæmophilia by ergotin, acetate of lead, laxatives (Glauber's salt), etc., is useless.

Henry Finch, from a successful experience with three cases, advises venesection in hæmophilia in conjunction with hot-water irrigation. By means of the latter the coagulation of the blood is rendered more rapid and complete. Wright praises the internal administration of the salts of lime prior to operation, these salts, as is well known, increasing the coagulability of the blood.

Entrance of Air into the Veins.—The unpleasant consequences of the entrance of air into the veins should receive special attention. It occurs exclusively after wounds of the veins in the neighbourhood of the thorax, or more particularly of the heart; amongst these veins are included the axillary, subclavian, jugular, etc. There is scarcely ever a positive pressure in these veins, and with every inspiration it becomes decidedly negative, so that air is sucked in when they are wounded—for instance, during an operation. Added to this, the veins in immediate proximity to the thorax gape open after being wounded, and fail to collapse because they are so closely attached to the surrounding connective tissue and fascia.

This is the case with the superior vena cava, subclavian, and internal jugular veins. Death only takes place when a large amount of air is sucked in at once; but single air bubbles are harmless, as they gradually disappear from the blood. Death from the entrance of air into the veins has been explained in various ways. According to Conty and Jürgensen, the air collects in the right side of the heart and prevents the contraction of the right ventricle, causing the heart to stop finally in diastole. The filling of the right side of the heart prevents the entrance of venous blood, thus stopping first the pulmonary and then the whole arterial circulation. According to others—Passet, for instance—the air passes from the heart to the pulmonary arteries, where it is arrested, interrupting the pulmonary circulation and preventing the left ventricle from filling with fresh blood. According to a third theory, air embolisms in the cerebral arteries furnish the principal cause of death.

Recently Hauer has studied the subject, experimenting chiefly on rabbits, and has come to the conclusion that death is principally the result of air embolisms in the small pulmonary vessels, and that death can likewise be caused by embolisms in the cerebral vessels, as small air bubbles pass through the pulmonary circulation into the left ventricle. The introduction of air into the veins has long been made use of as a method of producing death experimentally in animals. Rabbits are very sensitive to air in the veins, while in dogs eight to ten cubic centimetres of air can be injected into the central end of the jugular vein without a fatal result.

In man, the aspiration of air into the veins has hitherto been observed to occur principally during operations in the neighbourhood of the thorax (*région dangereuse*). Greene has collected sixty-seven cases with twenty-seven recoveries, but a large proportion of these are untrustworthy. The air is generally aspirated with an audible sucking, gurgling sound, and in the worst cases death occurs immediately. If the amount of air taken in is small, the patient will recover, though König saw in such a case great anxiety, with laboured breathing and dilated pupils.

Treatment of Air in the Veins.—Our treatment of this condition amounts to very little. As prophylaxis, operations in the neighbourhood of the great veins, particularly in the neck, should be conducted with the greatest care. If a large vein is wounded and air is sucked in, the opening in the vein should be immediately stopped with the finger, especially during inspiration, and the wound filled with an aseptic fluid, perhaps squeezed from a sponge, as air only gets into the vessel when the wound is dry. Sometimes the air bubbles are forced out of the open vein during expiration, and on this account Fischer has suggested that vigorous expiratory movements be made by compressing the thorax. The vein is then to be ligated as quickly as possible to prevent any further entrance of air. If a large amount of air has already been sucked into the vein and has reached the heart, further treatment is, of course, useless, for death in such cases is usually instantaneous.

Other Causes of Death during an Operation.—These, aside from the cases of actual malpractice, are usually due to the large amount of blood lost; to the particular kind of operation and the length of time it takes; to the excessive loss of body heat, especially in operations in the peritoneal cavity; and, finally, to the constitution of the patient. These subjects are fully discussed in another chapter.

§ 22. **The Post-operative Treatment of Patients.**—The student is referred to the *specielle chirurgie* for the after-treatment of individual operative cases.

The general treatment of the patient is very simple if, as usually happens, the healing process runs a normal course. After the operation has been performed and the dressing applied, the patient is put to bed and surrounded, when necessary, with warm bottles, not too hot, which are usually wrapped in flannel to prevent them from burning the skin. The position of the patient should be as comfortable as possible, with especial reference to the part of the body which has been operated upon. Old people, those suffering from emphysema, etc., should not have their head and thorax placed too low, as dyspnœa or

a hypostatic congestion of the lungs may easily occur. Immediately after the operation the symptoms which are the result of the narcosis become more or less prominent. For their treatment, see page 34.

It is very important to take the temperature two or three times a day with a reliable thermometer, and also to keep run of the pulse. Recovery usually takes place without fever, the latter being the result either of imperfect asepsis during the operation or of a fever existing before the operation. Every wound fever is caused by the absorption of toxic substances from the wound into the general circulation. The so-called aseptic wound fever (Volkmann, Genzmer), which probably depends upon the absorption of blood or fibrin ferment, is but seldom seen. In general, it has been my experience that in all cases where fever follows operation there will be found a corresponding disturbance of the normal course in the healing of the wound. For the details of the nature and treatment of this fever, see § 62.

The greatest pains, therefore, must be expended on a careful supervision of the healing process. The dressings should be changed if it is called for on account of fever, pain, or for the removal of drainage, stitches, etc., or if the dressings become loosened, displaced, or saturated by the secretion from the wound. The diet should be reduced in quantity, since the need of nourishment is less because of the rest in bed and the lack of exercise. Weak individuals should be given plenty of wine, and light, easily digestible, but strengthening food. For quieting the patient or for allaying pain, morphine should be administered in the form of a subcutaneous injection (0·01 to 0·02 gramme). But morphine must be used with caution; while some individuals can take very large doses with impunity, others will manifest symptoms of poisoning after very small doses. Next to morphine, the best hypnotic is chloral hydrate (Liebreich), two to three to five grammes of which, given in a glass of water, will usually induce sleep very quickly. But patients soon get used to the drug, and it then becomes more or less ineffectual and may produce gastric irritation. Of the new hypnotics, sulphonal and paraldehyde are very good.

§ 23. **The Most Important Causes of Death after Operation** are briefly as follows: Collapse; shock; anæmia; secondary hæmorrhage; poisoning from the drugs used with the dressings, such as iodoform, carbolic acid, bichloride of mercury, etc.; and particularly the wound diseases which come from infection with micro-organisms—erysipelas, pyæmia, and septicæmia, which will be described in their proper places.

We aim to prevent the infectious diseases by the most rigid asepsis during the operation, to prevent poisoning by the cautious use of antiseptics, and secondary hæmorrhage by the most careful ligation

of bleeding points in the wound. We try to make the amount of blood lost during the operation as small as possible by the methods formerly described (see § 18 and § 19). The best means to prevent an impending collapse from hæmorrhage is the transfusion of defibrinated blood; or, better still, of a 0·6-per-cent. solution of sodium chloride into the circulation or subcutaneously.

Recent experiments have demonstrated that the injection of a 0·6-per-cent. solution of sodium chloride into the general circulation is, on the whole, better than transfusion of blood. (For particulars, see § 89.) Patients suffering from acute anæmia should also be given plenty to drink, and wine especially. If collapse comes on, subcutaneous injections of camphor (1 to 5 of olive oil) and ether should be given with the hypodermic syringe. In severe cases this hypodermic administration of camphor and ether may be repeated several times at intervals of a few minutes.

Neuroses following Operation.—Sometimes after operations neuroses of the most varied sort will occur, especially hysterical phenomena, melancholia, nervous delirium, etc. They are most common in nervous neurasthenic subjects, and are manifested in their most pronounced form when the anæsthesia has been deep and prolonged.

The Influence of Constitutional Anomalies on the Healing of the Wound.—Emphasis has justly been laid upon the fact that the wound will run the normal course in healing if the operation has been performed with the most rigid observance of asepsis.

But there are chronic diseases, constitutional derangements in the nutrition of the tissues, which occasionally influence the course of healing in the wound (Verneuil, Paget). To this class belong especially chronic endarteritis, gout, alcoholism, syphilis, Bright's disease, diabetes, scurvy, malaria, leucæmia, pernicious anæmia, the morphine habit, etc.

Individuals suffering from chronic heart or kidney disease generally have little power of resistance, and not infrequently collapse after a slight and insignificant operation. As Lloyd has remarked, disease of the kidney can be so intensified by ether or chloroform narcosis that threatening symptoms of a collapselike nature may make their appearance. These chronic diseases will sometimes cause a great retardation in the healing of the wound made during the operation. It is well known how badly wounds heal in persons afflicted with scurvy, lucæmia, pernicious anæmia, and diabetes. Operations should be carried out with every antiseptic precaution in the case of pregnant women; while in children less than a year old, as well as in the very aged, great care must be taken to prevent unnecessary loss of blood.

CHAPTER V.

THE DIFFERENT WAYS OF DIVIDING THE TISSUES.

1. Division of soft parts (in which bleeding occurs).—The different forms of knives.—The way to hold the knife.—Instruments to assist in the cutting (thumb forceps, hooks, clamps).—Division of the soft parts by scissors.—Perforation of soft parts by puncture (trocar, hollow needle, hypodermic, aspirator). 2. The so-called bloodless division of the soft parts with the assistance of the ligature; by tearing the parts; by compression; by the hot iron, Paquelin's thermo-cautery, or the galvano-cautery.—The destruction or division of the tissues by the use of chemicals (caustics). 3. The division of bones by the chisel, saw, bone forceps. drill, osteoclast, etc.

§ 24. **The Division of the Soft Parts (accompanied by Loss of Blood).**—The soft parts can be divided in such a way that bleeding may or may not occur. The knife is the most frequently used instrument for dividing the tissues. The most useful forms are illustrated in Fig. 35.

1. The scalpel with the blade immovable on the handle (Fig. 35, *a–f*).

Fig. 35.—Different forms of knives.

2. Bistoury for the pocket case. The blade can be shut into the handle (Fig. 35, *g*).

3. Lancet (Fig. 35, *h*). This form of the knife is old-fashioned, and

is but little used at present, except the so-called vaccination lancet (Fig. 35, *i*). Its point has a shallow groove for carrying lymph or vaccine virus.

As shown in the illustrations, the blades of the scalpel and bistoury have different shapes, some being decidedly or slightly convex, or straight or curved to a greater or less degree. The points of the blades are also different, the so-called probe-pointed knife (Fig. 35, *f*) being blunt at the end. A. Cooper's probe-pointed knife (Fig. 36), with a decided curve to the blade, is very useful. Many knives are double-edged or lance-shaped (Fig. 35, *e*). We use the probe-pointed knife in those cases in which we wish to avoid injury to the adjoining tissues by the point of the knife. The length and breadth of the blade varies with the kind of operation in which it is intended to be used, the strongest, longest, and broadest knives being for amputations, disarticulations, and joint resections. For particular operations there are especially designed knives. The handle of the knife is of wood, horn, ivory, steel, glass, etc., and the end is usually made like a chisel, to facilitate tearing through the tissues when necessary. A nickel-plated metal handle is best adapted for the necessary sterilisation of the knife by boiling in a one-per-cent. soda solution.

Fig. 36. Cooper's curved knife.

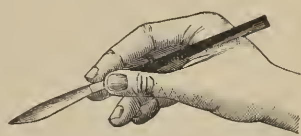


Fig. 37.—Penholder method of using the knife.

The usual ways of holding the knife are illustrated in Figs. 37 and 39, but I do not lay down strict rules when to use this or that method. No regular rules are needed by any one having a natural aptitude at operating, or by any one who is familiar with dissection. Large knives, like those used for resection, are held as pictured in Fig. 39. The amputation knife is grasped in the closed fist, as in Fig. 41. On the other hand, the lancet is held as indicated in Fig. 42.

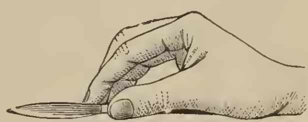


Fig. 38.—Fiddle-stick method of holding the knife.

Fig. 39.—Method of holding a large knife (resection knife).

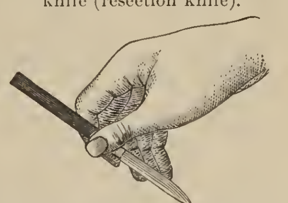


Fig. 40.—Method of holding the knife when the tissues are divided from within outwards.

The skin is usually divided as follows: After making the skin tense by the thumb, index, and middle fingers, the incision is begun by the scalpel, held in the right hand, as shown in Figs. 37, 38, or 39, and the blade is drawn between the above-

named fingers. Or a fold of skin is lifted up at right angles to the direction of the intended incision, which is then carried down through the fold. If it is desired to make a long incision at one stroke, the knife should be drawn rapidly along without applying much pressure.

We frequently cut from within outwards, as in the division of a fistulous tract, when the knife is held as in Fig. 40. For this purpose grooved probes or directors are commonly used (Fig. 43). In many operations, as we shall see, this director is indispensable, and it is especially valuable for the beginner. In such cases the director is pushed under the particular layer of tissue, or into the fistulous opening, and the point of the knife, cutting edge upwards, is pushed along in the groove, thus dividing the tissues. The cutting can be done from in front backwards, or *vice versa*, according to the case in hand. In conclusion, mention should be made here of the ear, myrtle-leaf, and rounded end probes (Fig. 44, *a*, *b*, *c*). These probes are usually used for diagnostic purposes, such as exploring fistulous tracts in soft parts and bones, in the search for foreign bodies, such as sequestra, etc. Probes made of silver, so that they can be bent, are the best. Before use, every probe should be disinfected as carefully as possible. There will be opportunity enough for warning against too much probing of tissues, but it is worth while to give a general caution on this subject now. In searching for foreign bodies the magnetic needle has been frequently used with success (Kocher, Kälin, Lauenstein, Graser, and others).

FIG. 41.—Method of holding a large amputation knife.

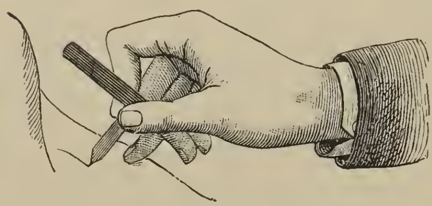


FIG. 42.—Method of holding the lancet.

FIG. 43. Grooved directors.

FIG. 44. Probes.

FIG. 45. Tenotome.

Mention should be made of the subcutaneous incisions which are employed for such cases as the division of contracted tendons, club-foot,

Fig. 46.—Toothed forceps.

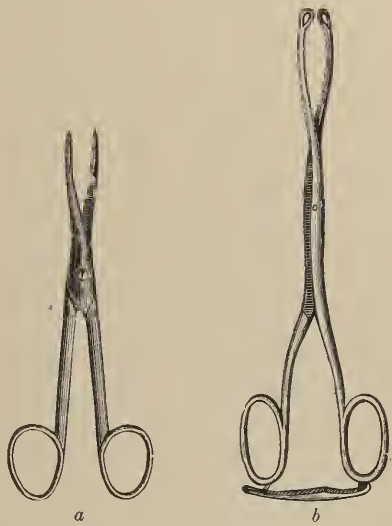


Fig. 47.—Dressing forceps (*a*); Luer's forceps with a clasp on the handles (*b*).

etc. The so-called "tenotomy knife" is used for this purpose; it is a small, sharp-pointed knife with a curved blade and a stout handle (Fig. 45). With this knife the skin is punctured, and the tendon is divided beneath the skin without cutting through the latter.

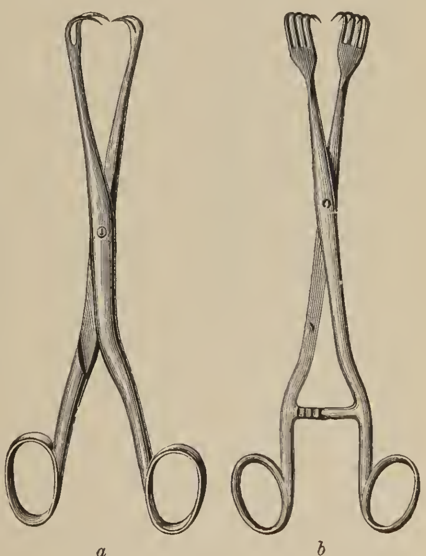


Fig. 48.—Muzeux's toothed forceps: *a* without, *b* with a clasp on the handles.

For holding and retracting the tissues after division of the integument we use particular instruments, especially the surgical thumb forceps, clamps, and hooks. Surgical thumb forceps differ from the anatomical kind in having two to four small teeth at the end of the blade, to enable them to get a better hold on the tissues. Hooked thumb forceps (Fig. 46), fitted with rather long, curved hooks, are excellent for certain purposes,

such as seizing small cutaneous tumours. The larger hooked thumb forceps of this kind can be closed and locked by a spring (Fig. 46, *b*). There are numerous other kinds of forceps for grasping the tissues, sharp and blunt, and of various shapes for the particular kind of operation in which they are intended to be used. Amongst the blunt-bladed variety are the sequestrum forceps (Fig. 47, *a*), straight and bent, and Luer's forceps, which have on the handles a self-locking ratchet to hold them closed. Another kind is the well-known forceps of Muzeux, which are straight or bent, and are provided with hooks (Fig. 48, *a*, *b*). These hooked forceps have from two to eight or more curved, sharp hooks on the end of the blades.

For making counter openings quickly and without loss of blood, Wölfler uses a cutting sequestrum forceps, which is made with one blade prolonged into a lance-shaped point, so that it can either be protruded beyond the other blade of the forceps (unsheathed perforating forceps), or by withdrawing the sharpened blade the latter is easily covered (producing the sheathed perforating forceps). The sheathed forceps are suited for those cases in which, to make a counter opening, a considerable mass of soft parts must be traversed, as in compound fracture, extensive phlegmonous processes, for making counter openings at the bottom of the true pelvis, etc.

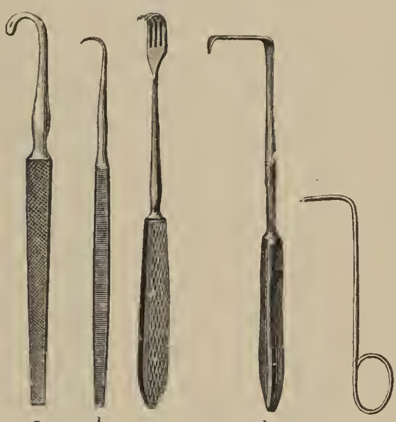


Fig. 49.—Retractors.

After making the skin incision the margins of the wound are held apart by blunt or sharp hooks, to enable the operator to obtain a better view of the deeper-lying parts or to divide them. Retractors (Fig. 49) are either simple, blunt hooks, like an aneurism needle used in tying a vessel (Fig. 49, *a*), or an ordinary sharp hook (Fig. 49, *b*) with one or more tines (Fig. 49, *c*), or a blunt hook bent at a right angle (Fig. 49, *d*, *e*). The single or double tined sharp hooks are also frequently used instead of the thumb forceps.

The scissors commonly used are straight or curved (so-called Cooper's scissors), or they have a kneelike bend. The various kinds of scissors designed for particular operations are described in the book on special surgery. The scissors are held for operating in the way we have learned to handle them in anatomical practice. I frequently give the

preference to scissors, especially in the removal of tumours, as they facilitate rapidity in operating. Afterwards they come into requisition for cutting ligatures, sutures, in the removal of stitches, etc.

Puncture of the soft parts can be done with a pointed knife, or a trocar or hollow needle, for the evacuation of fluid—e. g., from the pleural or peritoneal cavities, or from the scrotum; or for diagnostic purposes, to determine the nature of the contents of a cavity, or the nature of a tumour; or, finally, to introduce fluid medication into the tissues or general system.

A trocar (Fig. 50) consists of two parts, a stylet or trocar with a handle, and a tube or cannula enclosing the stylet. The cannula is provided with a metal shield at its posterior extremity. Trocars are straight or curved, the latter, for instance, being used for puncture of the bladder above the symphysis pubis in case of retention of urine. The calibre of the trocar varies with the uses to which it is intended to be put, the smaller sizes having the advantage that they cause only a small puncture, and the disadvantage that they take a long time to evacuate the fluid; and if the cavity contains a thick fluid, perhaps mixed with flakes of fibrin, the liquid may finally cease flowing from obstruction in the cannula. The method of holding the trocar for making a puncture is illustrated in Fig. 50. After it has been introduced far enough, the shield of the cannula is grasped by the left hand, the stylet or trocar is withdrawn, and the fluid then escapes through the cannula, which is left in place. The trocar and cannula, as the instrument is commonly called, must be used with every antiseptic precaution; care must also be taken that the puncture is not made above the level of the fluid, and that air does not enter the cavity into which the instrument is introduced. Before using, the trocar and cannula must always be boiled for five to ten minutes in a one-per-cent. soda solution.

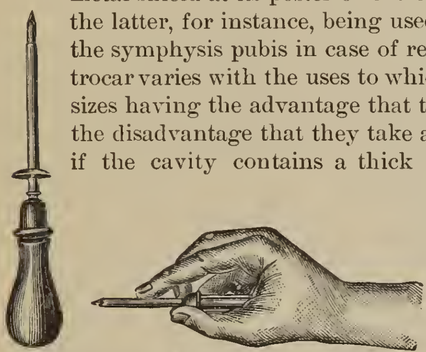


Fig. 50.—Trocar. Method of holding the trocar in making a puncture.

In former times, before these precautions were taken, and when neither the skin area in question nor the instrument were disinfected, this trifling operation was sometimes accompanied by infection of the albuminous contents of the cavity, with ensuing septic inflammation. To prevent the entrance of air, for instance, into the pleural cavity, Fergusson, Fraentzel, and others have fitted the trocar with a certain contrivance which will be described in the text-book on special surgery (Puncture of the Pleura).

For diagnostic purposes, the exploratory puncture is made with a very fine trocar, or, better still, with a hypodermic needle (Fig. 53) having a tight-fitting piston and joints. After inserting the hollow needle of the syringe, the graduated piston-rod is slowly withdrawn, thus causing the fluid contents of a cavity to flow into the barrel of the syringe.

For aspiration of the contents of a cavity, Dieulafoy, Potain, and others have made a suitable apparatus and have introduced it into general use. Syringes have also been constructed on the plan of Weiss's stomach pump for syphoning off or pumping out fluid from some part of the body.

Dieulafoy's Aspirator (Fig. 51) consists of a cylinder with a capacity of forty-five to fifty grammes, fitted with a graduated piston-rod which is notched at *A*, and, after being withdrawn, can be held fast at *B*. At *C* and *D* are two stop-cocks, which can be opened or closed, and the hollow needle is connected with the syringe by a rubber tube. Before puncturing with the needle it is best to withdraw the piston and form a vacuum in the barrel of the syringe, so that during the operation there can be no disturbing of the needle with tearing of the tissues. Both stop-cocks *C* and *D* are closed; the piston is withdrawn and retained at *B* by turning it slightly from left to right. The cavity of the cylinder is now relatively a vacuum. The upper end of the rubber tube is then fitted on the stop-cock at the end of the cylinder, while the hollow needle attached to the other end of the tube is plunged into the cavity in the body which it is desired to empty. The stop-cock *C* is opened and the liquid flows into the cylinder. To empty the cylinder of the liquid, the cock *C* is closed and *D* is opened, and by pushing down the piston the liquid flows out of *D*. If necessary, this can be repeated one or more times. Aspiration can also be practised by thrusting the needle into the tissues first, and then, after closing the cock *D*, opening *C*, and by withdrawing the piston, the fluid is allowed to flow into the syringe. If the instrument is in good condition and is managed correctly, it is impossible for air to enter the cavity as a result of the puncture.

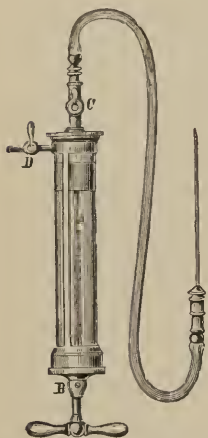


Fig. 51.—Dieulafoy's aspirator.

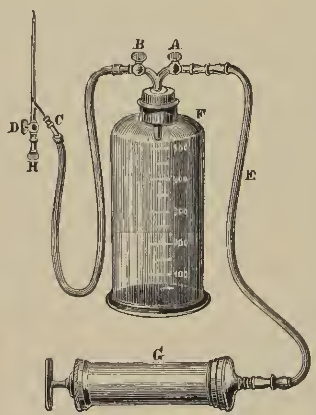


Fig. 52.—Potain's aspirator.

Potain's Aspirator (Fig. 52) consists of a graduated glass flask *F*, which is closed by a rubber stopper, and has a capacity of five hundred grammes. The rubber stopper is pierced by a metal tube divided into two compartments, one communicating with *A*, the other with *B*. One rubber tube *E* goes to the pump *G*; the other, which is fitted with a glass tube *C* to enable the liquid to be seen as it passes, is fastened to the lateral portion of the cannula of a trocar. The cannula is fitted with a stop-cock *D*. This apparatus is used in the following way: The cock *B* is closed, *A* is opened, and a

vacuum is made in the flask by means of the pump *G* ; then *A* is closed, and the puncture is made with the trocar. The stylet *H* is then pulled out, and the cannula is closed by the cock *D*, while *B* is opened, thus allowing the liquid to flow out through the cannula, glass, and rubber tubes into the glass vessel. During the aspiration the suction can be increased by opening the cock *A* and working the pump *G*.

The new aspirator invented by Debove, in which all stop-cocks are done away with, is a most excellent instrument. By a quarter turn of the handle the lateral openings of the cannula and trocar can be made to correspond, and thus allow the fluid to escape. The apparatus can be easily cleaned (Illustr. Monatssch. der Arzt. Polytech., June, 1889 ; this also contains a description of the automatic aspirator of Ruault).

Finally, we often puncture the tissues with a hypodermic needle or a similar instrument to introduce morphine, cocaine, ether, camphor, mercury, etc., into the neighbouring tissues or the general system. The hypodermic syringe usually contains one gramme, and the piston-rod is suitably marked off to permit an accurate measurement of the amount of medicament administered. After filling the barrel of the syringe with the fluid to be used, the hollow needle, having been carefully disinfected, is put in place, and the air is driven out of the syringe by holding the point upwards and gently pushing on the piston. To make the injection, a fold of skin is pinched up, the needle is plunged into the subcutaneous tissue, the syringe is emptied, the fold of skin is released, the needle is withdrawn, the tip of the left index finger is placed upon the point of puncture, and the injected fluid is evenly distributed by gently rubbing the area with the index and middle fingers.

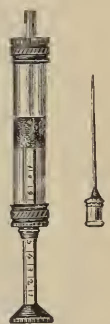


Fig. 53. Hypodermic syringe.

For making parenchymatous injections (that is, injections of medicated fluids into organs—e. g., muscles, glands, joints, etc.) it is customary to introduce the fluid at more than one point, particularly if large amounts of a medicament are to be administered.

The Care of a Hypodermic Needle.—To keep a hypodermic needle in a serviceable state, it should be washed out with water after use, and the traces of fluid should be blown out of the needle—or, better, dried out by heating the needle in a spirit lamp. This prevents the needle from rusting, keeps it from becoming stopped up, and makes it unnecessary to introduce a silver wire for rendering the needle pervious. To prevent the piston from drying and to keep it tight, it is worth while to introduce a drop of oil occasionally between the leather washers.

The small punctured wound made by the trocar or hollow needle can be covered with iodoform-collodion (one part iodoform, ten parts

collodion), or with a bismuth and bichloride-of-mercury solution; only exceptionally would an antiseptic dressing be necessary.

Chronically inflamed tissues, and more particularly those which have undergone caseous degeneration, are removed by scooping and scraping them out with sharp spoons (Fig. 54). The operation is called "scraping out" (sinuses, fistulæ, etc.). Sharp spoons are straight or slightly bent, and of different sizes. The open raspatory (Fig. 54, *a*), unlike the sharp spoon, has two sharp edges.

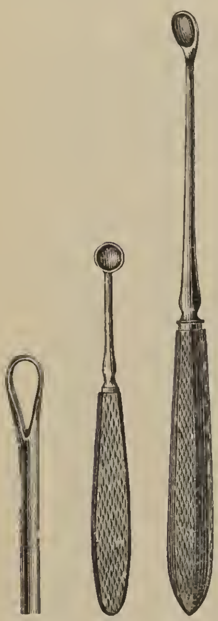

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Fig. 54.—Sharp spoon (Volkmann).

§ 25. **Bloodless Division of the Tissues, without Cutting, by Tearing, Twisting, etc.**—Under this heading comes, in the first place, the division of the tissues, especially the loose connective tissue, by means of the tips of the fingers, the handle of the scalpel or the director, thumb forceps, clamps, etc.; then the tearing out, or twisting off, or squeezing off of small tumours—for instance, from the larynx or the nose—by the use of special forceps. In all such cases the bleeding is so slight that the operation can in fact be called more or less bloodless. All large wounds produced by blunt instruments bleed but little, because the vessels are twisted and squeezed together in the process.

The Division of the Tissues by the Ligature, or Strangulation, is an antiquated method of operating; it is too slow, it is painful, and not infrequently gives origin to inflammatory and even dangerous suppurative processes. In former times the ligature was frequently used, and, in fact, there was a time when it was proposed to amputate the thigh in this way. The technique of its use is briefly as follows: The particular part in question—for example, a pedunculated tumour, a hæmorrhoidal protrusion, etc.—is tightly encircled about its base by a strong silk ligature or elastic band, less frequently by a strand of silver wire, and thus gradually death of the part takes place. The elastic ligature is best secured by passing its ends, kept at a proper tension, through a lead ring, the sides of which are then pinched together by a pair of nippers. The silver-wire ligature is applied, and then retained by twisting the ends around each other.

To prevent a ligature tied about the base of a tumour from slipping, the base is transfixed in suitable cases by one or two long needles and the ligature is placed beneath them; or the broad base of a tumour is tied off in two or more portions by transfixing the base with a needle bearing a double ligature, which is cut apart and tied around each half of the base. In parts of the body like the pharyngeal cavity or the intravaginal portion of the uterus, where the application of a ligature is difficult, special ligature carriers used

to be employed for applying and tying the ligature (Koderik's, Desault's ligature carrier, etc.). These were used for cases like tumours with a large, strong pedicle, in which the ligature, without being removed, had to be gradually tightened to finally attain the desired object. Koderik's instrument is fitted with an ivory knob perforated for carrying the ligature, the ends of which are made fast to a winch. By turning the winch the ligature is shortened and tightened. Gräfe's ligature carrier is almost exactly similar to the wire écraseur of Maisonneuve (Fig. 56), except that a silk thread is used instead of a wire. As I have said, the ligature is properly considered out of date at present, and it is only rarely to be used as, for instance, in the case of individuals who are hypersensitive about the use of a knife, or for the so-called "bleeders" (see pages 57–60).

Ecrasement.—*Écrasement linéaire*, as it is called by Chassaignac, who devised and introduced it, is also a form of division of tissues by ligature. The tissues are divided, or rather compressed, and thus necrosis takes place in the line of pressure (Fig. 55). The chain of Chassaignac's écraseur is like a chain-saw without teeth, and is made to encompass the portion of tissue to be removed, or is passed through a fistulous tract by a probe, or is carried through the parenchyma of an organ by a needle, and so around part of the organ, as in grasping a portion of the tongue. In the two latter instances the chain of the écraseur is first applied and then laid in the shank of the instrument. By means of the thumb-screw at the handle end of the instrument the chain ligature can be shortened—that is, the portion of the tissue in the grasp of the chain is gradually cut through by pressure necrosis. Similar instruments have been brought forward by Luer and Charrière. In Luer's écraseur the chain ligature is shortened by attaching it to a toothed screw which, by being turned on a female screw, draws on the ligature. Charrière's instrument is very similar to Luer's, except that the chain is exposed and not covered by a sheath. The wire écraseur of Maisonneuve is fitted with a wire instead of a chain; by turning the thumb-screw at the handle of the instrument, the loop of the wire ligature is made smaller. Chassaignac and Maisonneuve have tried in vain to introduce écrasement more widely into operative surgery, urging as advantages of their method the absence of hæmorrhage, and particularly the diminished chances of the absorption of septic matter, as the lymphatics and

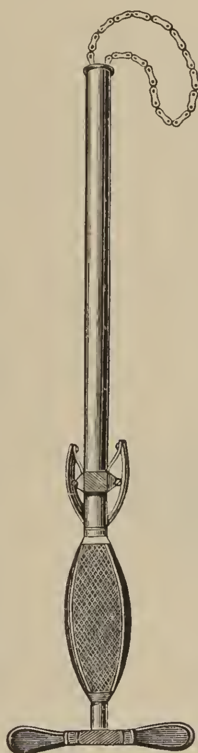


Fig. 55.—Chain écraseur (Chassaignac-Mathieu).

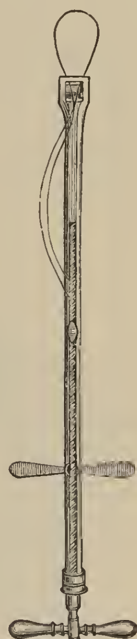


Fig. 56.—Wire écraseur (Maisonneuve).

connective-tissue spaces are more or less closed by pressure. But these statements are exaggerated, since, in the first place, there is no certainty that the écraseur, as it cuts its way through, will not cause hæmorrhage, especially from medium-sized arteries. Consequently it is not to be wondered at that écrasement should be superseded by the aseptic cutting operation, and that it should have passed almost entirely out of use. If we desire to divide the tissues with as little loss of blood as possible, we now use the actual cautery, or, better still, an instrument made of platinum and heated by the galvanic current (galvano-cautery) or benzene vapour (thermo-cautery of Paquelin).

The Cautery—The Paquelin Thermo-cautery.—The division of the tissues by the cautery (red-hot iron) is a very ancient method, and in the middle ages was used especially by the Arabian physicians. The ordinary cautery is made of different-shaped iron or brass rods with a wooden handle, and was formerly heated red-hot among glowing coals; but now it is usually heated in the flame of a Bunsen burner or a spirit lamp.

The old-fashioned cautery is at present entirely supplanted by Paquelin's thermo-cautery (Fig. 57). Every physician should possess

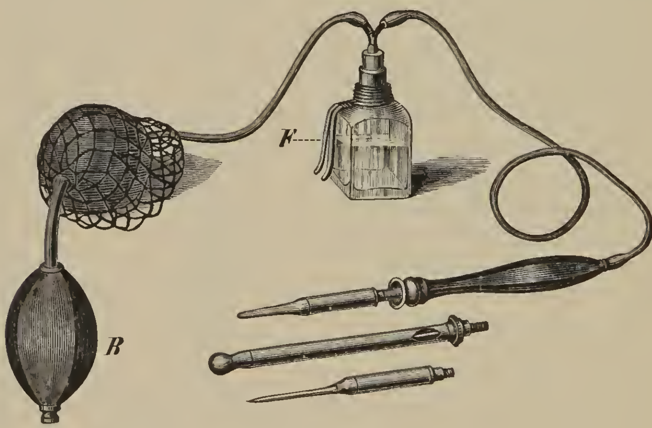


Fig. 57.—Paquelin's thermo-cautery.

one of these instruments. The apparatus works on the principle that platinum, after being sufficiently heated in the flame of a spirit lamp, will be made red-hot by the ignition, in the already hot platinum, of a mixture of air and vapour of petroleum ether (hydrocarbon compounds). In this process the petroleum ether is decomposed into water and carbonic acid, thus giving rise to so much heat that the platinum becomes red-hot. Paquelin's apparatus (Fig. 57) consists of a glass bottle half filled with petroleum ether (*F*). I use a mixture of two parts of benzine and one part of petroleum. The impure benzine

is better than that which is chemically pure. By squeezing the rubber bag *B*, the vapour of petroleum ether is driven out of the bottle through the rubber tube and through the hollow interior of the instrument into the hollow space inside the platinum tip. The thermo-cautery is managed very simply: The point of the instrument is heated in the flame of a spirit lamp for a couple of minutes, or long enough to reach a red heat, and then, by squeezing the rubber bag, the benzine-petroleum vapour is driven out of the bottle into the platinum of the instrument, where it becomes ignited. In this way a very excellent cautery is prepared, capable of very powerful action. The most useful tips are those with bulbous and knife-shaped extremities, like the so-called fistula cautery-tip illustrated in Fig. 57. Platinum scissors the blades of which can be made red-hot are not useful, and can always be dispensed with. The Paquelin thermo-cautery is in many respects better than the galvano-cautery, which will next be described; but the latter has the great advantage that it can be introduced cold—for example, into the nasal, oral, or pharyngeal cavities—and at any moment, by closing or opening the circuit, it can be brought to a red heat. The advantage of the Paquelin lies in its simplicity and cheapness. Paquelin has recently perfected his cautery so that it can be put to various uses, and can be employed in mineralogy, chemistry, bacteriology, etc.

Galvano-cautery. — The galvano-cautery was brought into general use by Middledorpf, and the excellent instruments that have been invented are of great service, though somewhat complicated. The most important of this type of instrument is the galvano-cautery made of a platinum wire sling (Fig. 58), which is tightened by turning the ivory thumb-screw *C*. At *A A* the instrument is connected with a battery by two conducting wires, and by closing the circuit the wire is brought to a red heat. By pushing the key *B* forwards or backwards, the current is made and broken. Instead of the expensive, frail, and so easily broken platinum wire, Voltolini has recommended the cheaper steel wire (piano wire) for use in the galvano cautery, and this answers every purpose perfectly.

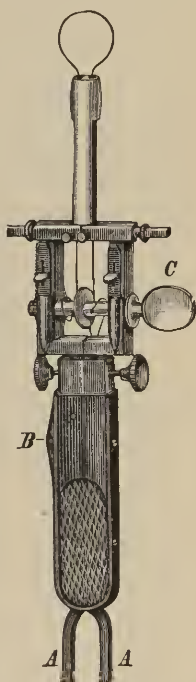


Fig. 58.—Galvano-caustic loop of platinum wire.

For managing the galvano-cautery loop with one hand, a special handle has been devised; one of the best is that of Bruns, which has

been recently improved by Böker (Fig. 59). There are three rings on this handle, for the thumb, index, and middle fingers respectively, the

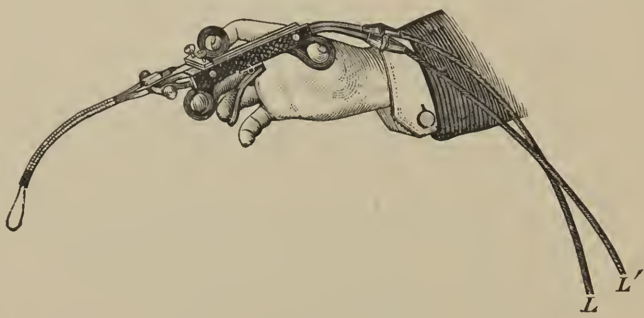


Fig. 59.—Handle (Böker).

fourth finger being held in the key which breaks and closes the circuit. The ring for the index finger is fastened to the movable cross-piece to which the wire making the loop is attached. By flexing the index finger, the corresponding ring, and with it the cross-bar and attached wire loop, are drawn towards the thumb, thus narrowing the loop. *L L* represent the two wires connecting the instrument with the battery.

Fig. 61.—Porcelain burner.

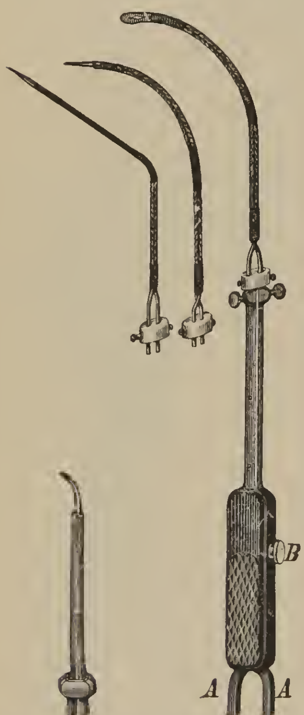


Fig. 60.—Various galvano-cauteries for the ear, nose, throat and larynx.

The other kinds of galvano-cauteries are variously shaped; besides the pointed and straight platinum points, or those which are more or less curved, there are the spatula-shaped, knobbed, conical, or spiral-shaped cauteries. By pressing the button *B* on the handle (Fig. 60) the circuit is closed. At *A A* are attached the wires connected with the galvanic battery. The so-called porcelain cautery (Fig. 61) consists of a conical-shaped piece of porcelain with a spiral of platinum wire. As to the battery for working the galvano-cautery, I use exclusively the zinc-carbon chromic acid battery of Voltolini (Fig. 62). We shall learn in the special surgery the particular cases for which the

galvano-cautery is suitable. It should only be mentioned in passing that even major operations—amputations, for example—have been performed by the galvano-cautery loop under exceptional conditions; for instance, to prevent loss of blood when a very high grade of anæmia is already present. Before the days of antisepsis, Hagedorn, by means of his écraseur loop, amputated a leg and a thigh without primary or secondary hæmorrhage, and without applying any ligatures. Bruns has also repeatedly used the galvano-cautery method to perform amputations. At present the galvano-cautery is no longer used for amputations, as they can be performed by the knife with the help of Esmarch's artificial anæmia without loss of blood, and at the same time the wound can be made to heal by primary union in a very short time—a thing which is impossible in the wound made by the galvano-cautery, as is always the case in a wound which is the result of a burn.

Battery of Voltolini.—Voltolini's zinc-carbon chromic-acid battery (Fig. 62) contains twenty-one zinc-carbon elements. The latter were originally combined in the so-called "chain"—all the carbon elements connected with each other on one side and all the zinc on the other. As this plan gave but little heating power, Voltolini improved the battery by adding a contrivance (*A*) for combining at will four pairs of elements, and thus succeeded in heating the porcelain cautery-tip red-hot. The fluid used in the battery consists of one part of bichromate of potassium, one part of concentrated (not fuming) sulphuric acid, and ten parts of water.

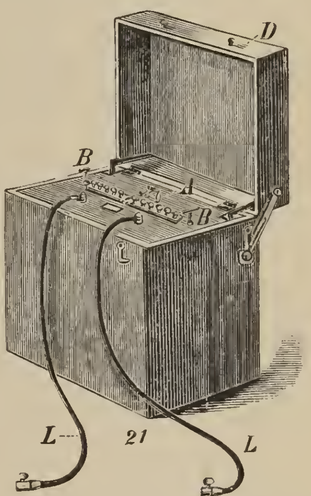


Fig. 62.—Zinc-carbon chromic-acid battery for the galvano-cautery.

To fill the battery, the cover of the box is lifted off with the attached elements by seizing the handles (*B B*, Fig. 62), and the glass vessel contained in the box is half filled with the above-described fluid. The elements are then replaced in the box and the connecting wires attached to the battery and the galvano-cautery instrument. After the cover (*D*) of the battery has been put back in its horizontal position, the fluid contained in the glass vessel inside the box surrounds the elements and the battery is ready for use. If the cover is only half shut, or remains open, as in Fig. 62, the glass vessel is displaced to the bottom of the box, the fluid does not touch the elements, and the battery cannot be used. The cover is retained at any desired angle by means of a rod fastened to it on the outer side of the box. After using the battery the elements are taken out of the box, carefully washed off with water, and dried. The zinc plates must occasionally receive a fresh amalgam of quicksilver; they are taken out of the battery, dipped in dilute sulphuric acid (1 to 7 or 10), and then treated with pure

mercury. To bring the mercury more thoroughly into contact with the zinc, it is rubbed into the plates of the latter with a tooth-brush or coarse paper.

Battery of Bruns.—The zinc-carbon chromic-acid battery of Bruns is an excellent apparatus.

Seiler's Battery.—Seiler has also introduced a new form of battery for the galvano-cautery. It consists of zinc-carbon elements in a fluid made of a mixture of sulphuric acid and bichromate of potassium; the elements are immersed in the fluid by turning a crank connected with a pedal. The operator keeps his foot upon this during the operation, and, by exerting more or less pressure with his foot, can regulate the strength of the current. To protect the surrounding parts from injury while the cautery is heated, Seiler has sheathed the part of his cautery instrument not intended to become red-hot, and the connecting wires in vulcanised rubber.

The present rapid advance in electricity enables us to make direct use of the electric current without using a battery; surgery will soon make use of this modern acquisition also, and thus electrolysis will have a new field opened up for itself.

All wound surfaces made by the cautery bleed but little or not at all, and are thus in a manner protected from infection, as the micro-organisms present at the time are destroyed, and the resulting dry eschar is an unfavourable soil for the lodgment of new ones. Moreover, wounds made by burning granulate vigorously, heal quickly, and form a cicatrix which has a marked tendency to contract. Suppuration does not always occur, and often enough wounds of this kind heal beneath the eschar with no dressing and without noticeable suppuration.

Electro-puncture (Electrolysis).—The so-called galvano-puncture or electro-puncture (electrolysis) is but little used at present. It consists in inserting platinum or gold needles, which are connected with the poles of a strong battery, directly into the tissue but not too far apart. The changes thus induced in the tissues are limited to the immediate neighbourhood of the needles. In other cases only a single platinum needle connected with the anode or cathode is inserted into the tissues in question—for instance, into a tumour—and a metal plate connected with the other pole is placed upon the skin. The negative pole (the cathode) appears to have a more powerful action than the positive (the anode). Recently electrolysis has come into more frequent use for operative purposes, especially in the case of tumours which are difficult of access, like naso-pharyngeal tumours, fibromata of the uterus, etc. In gynæcology the electrical treatment of women's diseases inaugurated by Apostoli has occasionally produced surprising results. I agree with Kuttner, that under certain conditions electrolysis offers us hopes of success, by being applicable to deeply seated regions when other means fail entirely.

Electro-puncture in Aneurism.—I have used electro-puncture in cases of aortic aneurism with very good results. It acts by exciting coagulation of blood in the aneurismal sac, which becomes diminished in size, and its walls are distinctly thickened. I use Stöhrer's zinc-carbon battery, and regulate the current by a dynamometer and a fluid rheostat. By means of the first the strength of the current can be determined each time it is used, and by means of the rheostat, made of a mixture of concentrated sulphuric acid and oxide of zinc, the process is made as painless as possible, since at the beginning one can allow the stream to increase in strength very gradually. At the close of the sitting the current is made to gradually decrease in strength by means of the rheostat. A sterilised fine steel needle ten centimetres long is plunged into the aneurism with every antiseptic precaution, the needle being connected with the anode, as the latter is preferable for causing coagulation of the blood, while the other pole (the cathode) is attached to a metal plate which is placed on the skin on the opposite side of the thorax. The length of the sitting should be five to ten minutes, and the strength of the current twenty to thirty milliampères.

The Destruction or Division of Tissue by Chemicals.—*Caustics.*—There are solid, soft, and fluid caustics which are used in the form of a paste, powder, or a fluid. At present caustics are used much less often than formerly for the destruction of soft parts. Of the solid caustics the most important are hydroxide of potassium or caustic potash, nitrate of silver. and sulphate of copper (bluestone).

Caustic Potash.—Caustic potash is applied in the form of a stick in a holder, thumb forceps, or wrapped in a piece of cotton for a handle. The most useful holder is an instrument made like a pair of pincers, having hollow jaws, with a contrivance for closing them made in the form of a movable blunt hook. As the caustic has a tendency to spread and "run" while being used, it is wise to carefully protect the surrounding parts. An old-fashioned way was to form an eschar on the skin by applying caustics between two pieces of sticking plaster, the one next the skin having a hole cut in it to permit the caustic to act upon the skin. This dressing was applied to any particular portion of the skin with compresses and bandages for six to seven hours, until the eschar formation was completed.

Nitrate of Silver.—Silver nitrate comes in the form of a cylindrical pencil, which is generally provided with a handle, and is applied to hasten the skinning over of a granulating surface. The sticks of silver nitrate—which, like our ordinary lead pencils, are enclosed in a wooden sheath—are most excellent. The so-called "modified stick" of silver nitrate is made of nitrate of silver and saltpetre (equal parts, or one part of the former to two of the latter). These sticks are less brittle and have a milder action. The action of bluestone (sulphate of copper) is still milder, and this material is used almost exclusively in diseases of the eye.

Other Caustics.—Amongst fluid caustics are the mineral acids, the most

useful being concentrated sulphuric acid and fuming nitric acid. Besides these there should be mentioned hydrochloric, acetic, monobrom-acetic, and bichlor-acetic acids; also concentrated solutions of lactic acid, caustic potash, bichloride of mercury, chloride of zinc, chromic acid, antimony, etc. The fluid caustics are injected into the tissues by a hypodermic syringe, and this can occasionally be practiced in inoperable cases, such as tumours. Of the milder caustics, the best known are the so-called "Vienna paste" and the pastes consisting of arsenic and of chloride of zinc.

Vienna Paste.—To make Vienna paste, five parts of caustic potash and six parts of quicklime are made into a thick paste, immediately before using, by the addition of the necessary amount of alcohol. The paste is then spread about five millimetres thick, by a wooden spatula, over the area selected for cauterisation, and allowed to remain from four to fifteen minutes, or until the desired effect is obtained. After six minutes at the latest there appears at the edge of the paste a grey line, which indicates that cauterisation or eschar formation is taking place in the area covered by the paste. After the removal of the paste the skin which it covered should be washed off with vinegar.

Arsenic Paste.—Make a dough of one part of arsenious acid and fifteen parts of starch and water. The eschar forms after a few days, during which there is severe pain. If too much paste is applied symptoms of poisoning are very apt to appear.

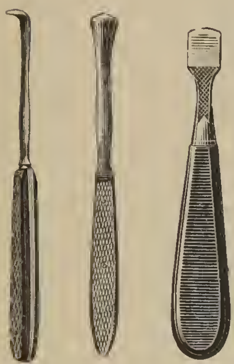
Chloride-of-Zinc Paste (*Canquoin's Paste*).—One part of chloride of zinc and two to four parts of flour, according to the amount of cauterisation desired, are mixed with just enough water to make a rather thick, stiff dough. The thicker the dough is spread out over the skin the more intense its action. Before applying the paste the epidermis should be removed, as it resists the cauterising power of the chloride of zinc. The action of this paste is very painful.

Rivallié's Caustic.—Rivallié has introduced a useful caustic. By dropping concentrated nitric acid upon charpie or cotton-wool in an earthen vessel there results a gelatinous mass, which can be picked up with forceps and applied to the skin, and after a quarter to half an hour a yellow circumscribed eschar forms. After about twenty-four hours the eschar can be in the most part separated, and the cauterisation may then be repeated. Not the smallest amount of bleeding results, even though the caustic be left in place for twenty-four hours, and the pain is very slight.

Caustic Points.—In conclusion, mention should be made of the method of cauterisation used by Maisonneuve (*cautérisation en flèches*). It is a very painful and slow procedure, which at present is scarcely ever used. By means of a sharp-pointed bistoury the superficial portion of a tumour is incised in lines radiating to its base, or else the base is punctured repeatedly all around, and in each of these punctures there is introduced a long pointed solid stick of some caustic, or the incisions are filled with pieces of cotton or strips of linen soaked in some fluid caustic.

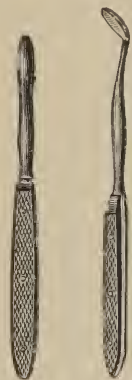
§ 26. **The Division of Bone.**—We use the so-called raspatory and periosteal elevator before dividing a bone, in order to raise and so preserve the periosteum—as, for example, in the subperiosteal resection of

the bone near a joint. The ends of raspatories—i. e., their blades—are sharpened (Fig. 63), and either curved (Fig. 63, *a*) or straight (Fig.



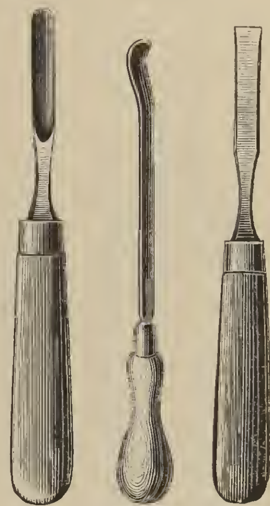
a *b* *c*

Fig. 63.—Raspatories: *a* and *b* are Langenbeck's, *c* is Ollier's.



a *b*

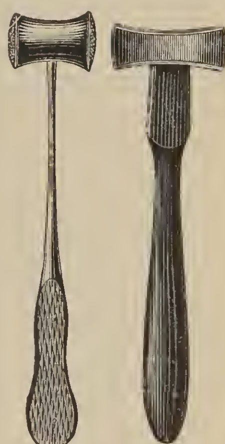
Fig. 64.—Elevators.



a *b* *c*

Fig. 65.—Chisels.

63, *b*, *c*). Elevators serve to pry off the periosteum without cutting it, and are therefore blunt-edged, and either straight or slightly curved (Fig. 64, *a*), or they are sometimes shaped like a goat's foot (Fig. 64, *b*).



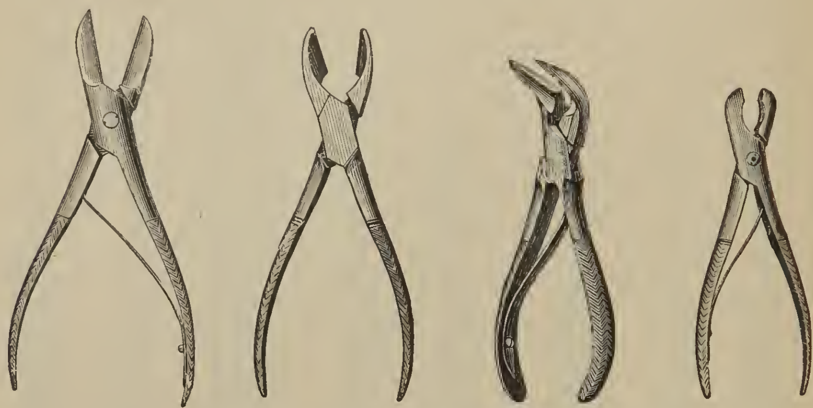
a *b*

Fig. 66.—Hammers for the chisels.

To remove a part of a bone or to completely divide it, we use chiefly the chisel or cutting bone forceps and the saw.

Chisels which are made of the best steel have either grooved (Fig. 65, *a*, *b*) or flat blades (Fig. 65, *c*). They vary much in strength, breadth, and length, and have their edge straight across or slanting. It is better to have the handle made not of wood, but of metal, in order that the sterilisation of the chisel by boiling may be more complete. The hammers used in chiselling (Fig. 66) are made of wood or metal. For dividing the large hollow bones I use the broadest form of chisel, as is recommended by König. And for these large, broad chisels I prefer wooden handles, which can be easily replaced if they become damaged by boiling in a one-per-cent. soda solution. They are not to be applied at right

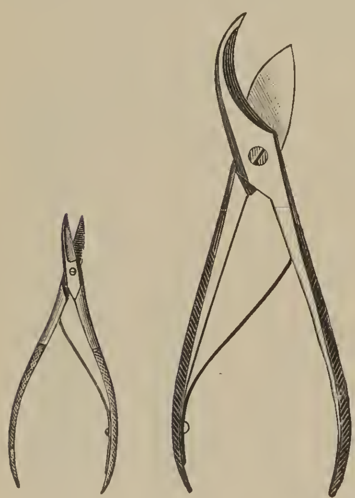
angles, but obliqnely to the long axis of the bone. In cases where it is necessary to chisel at some depth below the surface, and it is impossible



a *b* *c* *d*

Fig. 67.—Bone forceps: *a* and *b* are Liston's, *c* is Roser's, *d* is Luer's.

to keep perfect control of the action of the chisel, Roser recommends that the chiselling be performed with three hands; i. e., an assistant holds the chisel while the operator does the hammering, and with the index finger of his other hand controls the blade of the chisel.



a *b*

Fig. 68.—*a*, Bone-cutting forceps; *b*, bone-cutting forceps for use in resections of ribs.

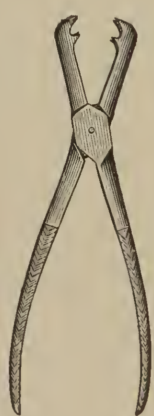


Fig. 69.– Forceps for holding a bone (Langenbeck).

The cutting bone forceps (Fig. 67) or bone shears (Fig. 68) is used to remove projecting angles or portions of bone, or to completely divide a flat bone like a rib, the lower jaw, etc. The rongeur or gouge forceps of Luer (Fig. 67, *d*) can also be used for holding a bone. The best forceps for grasping a bone, etc., is that of Langenbeck (Fig. 69). The bones of children, particularly the soft, half-cartilaginous epiphyses and spongy bones, like the carpal and tarsal bones, can often be

divided with a knife. The short, strong resection knife is the best suited for this purpose.

For sawing bone we use bow-saws (Fig. 70), narrow-bladed (Fig. 71), and chain saws (Fig. 72). The broad, flat saws have now passed entirely out of use. Butcher's saw (Fig. 70, *b*) is a very good one; its blade can be drawn tight or relaxed by means of the screw in the topmost crossbar, the latter being connected by a hinge joint, with the two bars running at right angles from its extremities. Thus these two bars, by means of the hinge joint, can exert traction in the line of the long axis of the saw blade, and the latter can make a curved cut in bone. For dividing small bones like the phalanges the so-called phalangeal (Fig. 70, *c*) or narrow-bladed saw is used (Fig. 71). The latter saw can be introduced through a punctured wound in the soft parts. The narrow-bladed saw is grasped in the closed fist and the index finger is extended so as to lie upon the back of the saw. For many operations Adams's narrow-bladed saw is one of the best (Fig. 71, *b*). Jeffray's (1784)

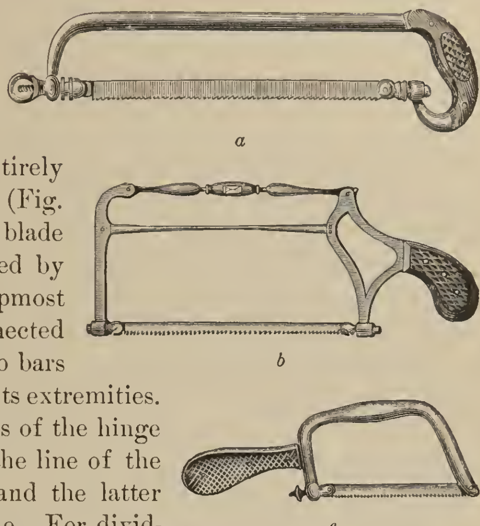


Fig. 70.—*a*, Bow saw; *b*, Butcher's saw; *c*, metacarpal saw.

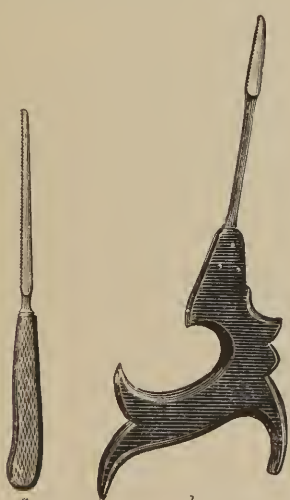


Fig. 71.—Phalangeal or key-hole saws: *a*, *b*, Adams's.

Fig. 72.—Chain saw.

Fig. 73.—Flexible director for the chain saw.

chain saw (Fig. 72) consists of numerous links connected by hinges, and each extremity of the chain is provided with a hook for connect-

ing it with the handles. The chain saw is carried around behind the bone either by the hand, or a ligature threaded on a blunt curved needle, or a curved probe with an eye at the end, or by an instrument like the one illustrated in Fig. 73. The guide in Fig. 73 is provided with an eye for the thread, by means of which the chain saw is brought in position for use—for example, behind the neck of the femur. The earlier instruments of this class were made of steel or iron; but I have substituted for them a copper rod which can be bent and which has a steel handle, and thus I can give it any bend I desire. The chain saw should be handled gently, and with moderate traction exerted at the most obtuse angle possible. If too much force is used the chain may break, and if the tension upon the chain is uneven it may become jammed in the bone. The compound chain saw (Heine's osteotome) consists of a chain saw which is stretched in the form of an ellipse over a tongue-shaped metal plate and is made to revolve, or rather is set in motion, by means of a crank. Heine's osteotome and similar instruments are unnecessary.

Rotation Saws.—Ollier, acting on the suggestion of the circular saw so widely used in the arts, has invented a "rotation saw" which is worked by a crank, and by means of which pieces of bone of any desired shape and size can be cut out. The circular or rotation saw of the dentist is also suitable for surgical operations; and mention should likewise be made of the different kinds of trephines made in the form of a round saw which are used for opening the skull.

Among other instruments used in bone operations are the sharp spoons (see page 81) for scraping bone which has become inflamed and broken down; also the different kinds of drills for making holes in bone—for example, to insert a bone suture (see Fig. 93). The bone files for smoothing and rounding off the edges of a bone—for instance, after it has been sawed across—are no longer used, but their place has been taken by the simple chisel or Liston's bone forceps.

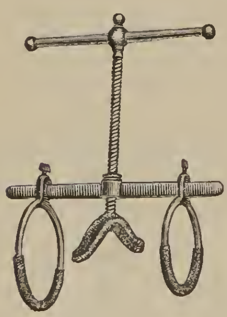


Fig. 74.—Rizzoli's osteoclast.

Osteoclasis.—Either the hands of the operator or special instruments (osteoclasts) are used to fracture a bone (osteoclasis) when, for example, a fracture has healed in a faulty position, or when there is a curvature of bone resulting from rhachitis. Collin, Robin, Mollière, Ferrari, Beely, and Gratteau have each devised osteoclasts.

Rizzoli's apparatus (Fig. 74) consists of two rings sliding on an iron bar, to which they can be made fast at any point by means of a thumb-

screw, and in these rings the extremity is placed. The "stamp"—i. e., the lower end of the screw-pin—is applied at the point where it is desired to break the bone transversely. By turning the lever the pin is screwed down and the stamp fractures the bone. The skin should be carefully protected at the different points of pressure by means of cotton or jute pads. In spite of the manifold improvements in the osteoclasts the instruments cannot even yet be relied upon to do all that their inventors claim. Above all, it is very difficult to fracture a bone at exactly the desired spot, especially if it is in the neighbourhood of a joint, without doing some injury to the soft parts.

CHAPTER VI.

THE METHODS OF ARRESTING HÆMORRHAGE.

The tying of vessels (ligation).—Artery clamps.—The preparation of aseptic ligature material (catgut, silk, etc.).—The substitutes for ligation.—Torsion.—Deep suture.—Temporary occlusion of the lumen of the vessel by artery clamps.—Ligature of a part of a vessel's wall and suture of veins.—Pressure.—Packing.—Cauterisation.—Other methods of controlling hæmorrhage.—Irrigation with hot and cold water.—The suture of the wound, with application of pressure by the dressings as a means of stopping hæmorrhage.—Old-fashioned and no-longer-used methods of stopping hæmorrhage (acupressure, acutorsion, etc.).—Ligature of vessels in their continuity. See also §§ 18 and 19 (Prevention of Hæmorrhage in Operations, Esmarch's Artificial Ischæmia).

§ 27. **The Arrest of Hæmorrhage during Operations.**—We distinguish between arterial, venous, and capillary or parenchymatous hæmorrhage. We will here discuss, in the first place, the arrest of hæmorrhage during an operation.

The arrest of hæmorrhage from a wound made in the course of an operation must be most carefully attended to, in order that no secondary hæmorrhage may interfere with the healing of the wound or endanger the life of the patient. It is, in general, an indispensable requisite for obtaining perfect primary union that all hæmorrhage should be checked completely. In the presence of dangerous hæmorrhage the qualities of a surgeon are revealed; coolness, presence of mind, and complete familiarity with the technique of operating are indispensable. We have already learned, in the consideration of Esmarch's bloodless method, in what way serious hæmorrhages may be prevented in any operation.

The first step in accurately checking hæmorrhage consists in tying off (ligation of) the vessels, both veins and arteries, which have been wounded in the course of the operation. In the preantiseptic days of surgery there was great dread of ligating veins, on account of the frequency of the ensuing suppurative changes which took place in the thrombi, resulting in a general systemic infection (pyæmia) and death. Modern antiseptic surgery, however, has no fear of ligating veins, and secures every bleeding vessel. If, for example, in a high amputation

of the thigh, or disarticulation of the femur, the femoral vein is not ligated, it is perfectly possible for dangerous, recurrent, or secondary hæmorrhages to take place; and as a matter of fact this has been observed.

Attempts to diminish or prevent hæmorrhage during an operation are as old as surgery itself. We recall with a shudder the times when amputation of a limb was performed with a red-hot knife, or when the amputation stump was plunged into melted pitch to check the bleeding. The skilful surgeons of the time of the Roman Empire understood the treatment of hæmorrhage better than the physicians of the middle ages, were familiar with the ligature, and even used artery clamps. All this was entirely forgotten during the middle ages, and Ambrose Paré reintroduced the ligation of vessels in the sixteenth century.

We tie off or ligate the vessels in the wound by seizing their open ends with so-called artery clamps or hæmostatic forceps which are

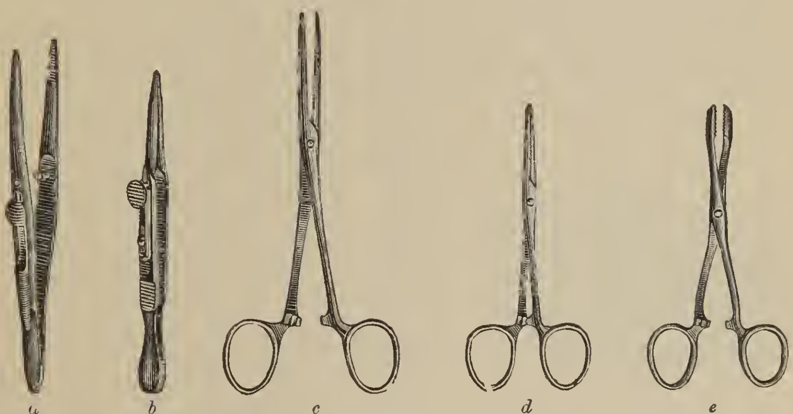


Fig. 75.—Hæmostatic forceps or clamps.

closed and locked by a suitable contrivance. The clamps which I consider the best are illustrated in Fig. 75, some being open and some closed. The Fricke-Amussat clamp (Fig. 75, *a*, *b*), which is fastened by means of a small sliding piece the end of which fits into a ring in the other jaw of the forceps, and Péan and Kœberle's forceps, which have a ratchet lock on the handle, are the most useful forms of the instrument.

By means of the hæmostatic forceps or clamps the isolated end of the vessel is seized, and, if necessary, the surrounding tissues are stripped back and the vessel is carefully encircled with catgut or silk, which is then tied beyond the clamp. In the case of large arteries the ligature should be tied in a double square or surgeon's knot; but small

vessels only require the ordinary simple knot. The ends of the ligature are cut short after the clamp has been first removed to see whether the knot holds securely and whether there is any danger of its slipping. The surgeon's knot is made by twisting one end of the ligature around the other—not once, as in tying the ordinary knot, but twice. The application of ligatures *en masse*, as they are called, about the vessel and the surrounding tissue should be avoided as much as possible. Instead of hæmostatic forceps or clamps, sharp-pointed hooks are sometimes used to draw out the end of the vessel. Ligatures are made of catgut, which was first recommended by Lister, and which is manufactured from the intestine of the cat or sheep, and silk which has been sterilised by boiling.

Preparation of Aseptic Catgut.—Catgut can be prepared for use aseptically in various ways. If the hot-air sterilisation plan of Döderlein, Kummel, and others is used, the raw catgut must first be soaked for twenty-four to forty-eight hours in absolute alcohol to remove all water. Then the catgut is put in a glass jar or between layers of blotting paper and placed in the sterilising apparatus, which is very gradually heated to a temperature of 130° C. After this it is placed for six to eight days in oil of juniper which has also been sterilised by heat, and then it is stored for use in a one-per-cent. alcoholic solution of bichloride of mercury or in a ten-per-cent. solution of carbolic acid in glycerin, or in a 1-to-500 aqueous solution of bichloride of mercury. Brunner places the catgut in xylene in a closed vessel, and subjects this to the action of steam at a temperature of 100° C. (212° F.) for three hours. The catgut is then washed in alcohol and stored in an alcoholic solution of bichloride of mercury. According to my experience, the hot-air sterilisation of catgut is difficult and troublesome, and I prefer the bichloride method of treating it devised by Schimmelbusch and Bergmann after the catgut has been previously rendered free of fat by soaking in ether. The sterilisation is accomplished as follows: the glass vessel and the glass spools are sterilised by steam for three quarters of an hour; the raw catgut, which contains fat, is rolled on the spools and soaked for twenty-four hours in ether, which is then poured off and replaced by an alcoholic solution of bichloride of mercury (ten parts of bichloride, eight hundred parts of absolute alcohol, and two hundred parts of distilled water), which is renewed at the end of twenty-four hours. According to whether one desires

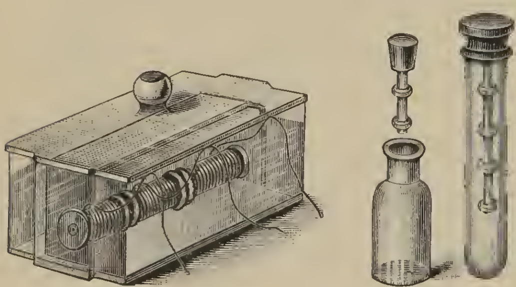


Fig. 76.—Vessels for storing sterilised catgut and silk: 1, Glass case with glass spools for hospital practice; 2 and 3, glass bottles with glass rollers and india-rubber stoppers for private practice (see also Fig. 14).

stiff or pliable catgut, the latter is stored in absolute alcohol, or in a twenty-per-cent. mixture of glycerin and alcohol, or in the alcoholic solution of bichloride just described. In this way a very strong, flexible catgut is obtained which is aseptic, and more desirable in every way than the carbolised catgut formerly used, which was not aseptic, and occasionally gave rise to suppuration, pyæmia, and septicæmia (Zweifel, Kocher).

Chromicised Catgut, which is more slowly absorbed, is prepared from commercial raw catgut by subjecting it to a dry heat of 130° C. (266° F.), and keeping it for forty-eight hours in a ten-per-cent. solution of carbolic acid in glycerin, and then for five hours in a one-half-per-cent. solution of chromic acid. It is stored in a five- to ten-per-cent. solution of carbolic acid in glycerin, or in a one-per-cent. alcoholic solution of bichloride of mercury, and immediately before use it is placed in a three-per-cent. aqueous solution of carbolic acid or bichloride of mercury. Macewen keeps the raw catgut for two months in a mixture of twenty parts of glycerin and one part of a twenty-per-cent. aqueous solution of chromic acid. He then washes it and stores it in a twenty-per-cent. solution of carbolic acid in glycerin.

Braatz uses the following method for sterilising catgut: the raw catgut is soaked in ether or chloroform for one or two days, to free it from fat; it is then placed for twenty-four hours in an aqueous solution of bichloride of mercury (1 to 1,000), or else sterilised by Reverdin's dry-heat method (page 88), and then stored in absolute alcohol. Many surgeons preserve their sterilised catgut in a dry state—for example, between layers of sterilised compresses, or in a glass jar (Esmarch, Mikulicz).

According to the investigations of Brunner, the catgut sterilised by treatment with bichloride of mercury, or by dry heat, is perfectly sterile, while the catgut treated with carbolic acid, chromic acid, and oil of juniper contains many fungi and bacteria. Brunner recommends the following method of sterilisation: the catgut is first washed with soft soap, and then, either immediately or after soaking for half an hour in ether, it is transferred to an aqueous solution of bichloride (1 to 1,000), where it is left for twelve hours. It is then stored in bichloride of mercury one part, absolute alcohol nine hundred parts, glycerin one hundred parts.

Preparation of Carbolised and Bichloride Silk.—The carbolised and bichloride silk is prepared by winding the silk on hollow glass spools and then boiling it for half an hour in a five-per-cent. aqueous solution of carbolic acid, or a 1-to-500 solution of bichloride of mercury. After this it is stored in a five-per-cent. aqueous solution of carbolic, or a 1-to-2,000 solution of bichloride of mercury, or in absolute alcohol. An aseptic silk ligature remains in a wound as a foreign body, but without causing any reaction.

Catgut has long been used for the ligation of vessels as well as for suture material, and for the latter purpose was used by Rhazes, while Hennen and Young (1813), Lawrence (1814), and A. Cooper (1817) used it for tying vessels.

Ligatures of Other Materials.—Besides catgut and silk, ligatures are made of chamois leather or parchment, from the aorta of the ox, from horse-hair, and from the tendons of mammals like the kangaroo, whale, reindeer, etc.

Catgut is absorbed and disappears without leaving a trace, while silk, on the other hand, remains unchanged. For ligation of the large

arteries and veins I prefer aseptic silk to catgut, as the latter may be absorbed too quickly before the cicatricial closure of the lumen of the vessel has become sufficiently firm. Moreover, silk can be sterilised by boiling with greater certainty than is possible in the case of catgut, and much finer ligatures of silk than of catgut can be used even for large arteries.

§ 28. **Substitutes for the Ligation of Vessels.**—*Torsion of the End of the Artery* (*Amussat*), *and Deep Suturing.*—Torsion of the cut end of a vessel is performed by seizing the end in a hæmostatic clamp and twisting it several times on its long axis. The lumen of the vessel is thus closed by rolling up and tearing the walls of the vessel, especially the middle and inner coats. Torsion produces more accurate closure of the lumen of the vessel if the latter is grasped by two clamps—one at the end of the vessel and held in its long axis, the other clamp behind the first and at right angles to the vessel. The first clamp is then twisted till the portion of the vessel to which it is attached gives way. Arteries as large as the brachial can be so firmly closed by torsion that no bleeding will occur. But if branches are given off close above the bleeding end of the artery, the latter will not be sufficiently movable to make torsion safe, and on this account torsion—for instance, of the femoral artery—is usually impracticable.

Torsion is, as a general thing, only used for small vessels. Stilling recommends drawing the end of the artery through a puncture made in the artery wall (Fig. 77).

Deep Suture around a Vessel ("Umstechung").—A suture passed through the tissues around a vessel is similar to a ligature *en masse*, be-

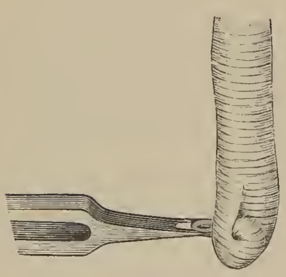


FIG. 77.—"Durchschlingung" of an artery (Stilling).

FIG. 78.—"Umstechung" of vessels.

cause the surrounding tissues, as well as the vessel itself, are included in the ligature (Fig. 78). A sharply curved needle, carrying a ligature, is passed through the tissues so that the points where it enters and emerges lie close together. This method is applicable for those cases

in which the bleeding end of the vessel lies, for instance, in stiff, unyielding tissues, or, for one reason or another, cannot be sufficiently isolated for the application of a separate ligature.

Hæmostasis by passing a Suture through the Skin into the Parts around a Vessel.—Middledorpf's method of passing a suture through the skin and around a vessel is at best only a temporary expedient. For example, in bleeding from the temporal artery a curved needle carrying a ligature can be passed through the skin under the vessel and then knotted upon the skin. A similar plan is sometimes adopted to render operations on the tongue bloodless. At the end of the operation, when the wound in the tongue has been closed by sutures, this ligature *en masse* is removed.

Temporary Occlusion of the Vessels by Clamps.—For cases in which the application of a ligature is difficult or impossible, it may be expedient to occlude the lumen of a vessel by a hæmostatic clamp, which is left in place for some time. Kœberle and Péan have found the lumen of vessels perfectly closed after the expiration of twenty-four hours with this method of hæmostasis.

Simple punctures or slits in the wall of a large vein have been closed by the application of a ligature to the side of the vessel. The injured portion of the vein is seized by a clamp, and, while slight traction is made upon it, a ligature is tied around the puncture beyond the jaws of the clamp, and thus the whole lumen of the vessel is not occluded. This lateral ligature is but little used, as it easily slips. If a large vein, like the common femoral, has been punctured, and there is fear of gangrene of the lower extremity if the whole vein is tied off, it is best to close the puncture temporarily with an artery clamp or by Schede's method of suturing with fine catgut. Schede has repeatedly sutured veins by means of the finest needles and catgut with excellent results. Under this heading come suture of the femoral, inferior vena cava, axillary, jugular, etc.

Experimental Investigations on the Suture of Arteries and Veins.—The experiments of Horoch prove that suturing an artery, as well as ligating it, results in a perfect closure of the lumen of the vessel by means of a clot. But ligation causes immediate occlusion of the vessel, while suturing causes occlusion to take place slowly. Catgut is not suitable for sewing an artery, but only fine silk should be used. If a vein is sutured, the lumen persists to a greater or less degree, and consequently Horoch prefers suture to the application of a lateral ligature, as the experiments of Blasius show that lateral ligation of a vein regularly causes occlusion of the latter's lumen by a thrombus. Jassinowsky, Burci, Muscatello, and others have also made experiments with suturing a partially divided artery in animals, and have obtained satisfactory results. With the aid of the sutures the wound in the artery unites by primary intention, and there is no hæmorrhage following the operation. Secondary hæmorrhage, thrombosis (contrary to Horoch's experience), and the formation of aneurisms, do not occur. The lumen of the vessel where the suture was applied remains entirely free. Suturing of the vessel's wall is particularly applicable in longitudinal, oblique, and "flap" wounds, provided that not more than half the circumference of the large vessel is involved in the wound. The most rigorous asepsis is absolutely essential for success in

suturing a portion of the wall of an artery, for which the finest silk is used in the form of a continuous suture passed gently through the adventitia and media. Hitherto suture of an artery in man has never been practically tested.

§ 29. **Other Methods of Hæmostasis.**—Another most important method of hæmostasis is *pressure*, which we apply in many different ways, and which is evidently the simplest and most natural way of checking hæmorrhage. Whenever during the course of an operation blood gushes forth from a divided vessel, we immediately place our finger upon the bleeding point and so stop the hæmorrhage. It is singular that this simple method of hæmostasis is so little understood by the laity; when they meet with dangerous bleeding, perhaps from a punctured wound of one of the larger arteries, they are very apt to employ the strangest remedies, such as, for example, the application of cobwebs and similar things. Pressure is also practised as a temporary means of hæmostasis in the form of digital compression (mentioned in § 18, p. 47) of the afferent artery, and by means of rubber bandages, tourniquets, etc. In suitable cases pressure can be combined with forced flexion of the neighbouring joint—as, for example, in bleeding in the popliteal space the knee joint is immobilised in extreme flexion (Fig. 79), or hæmorrhage from near the elbow can be held in check by immobilisation of the elbow joint in a position of extreme flexion.

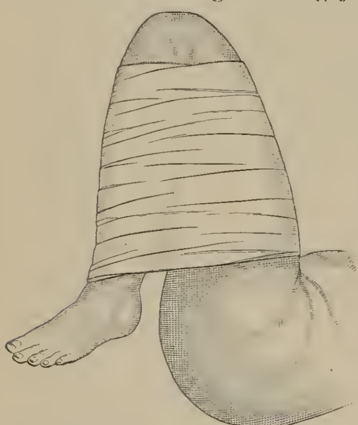


FIG. 79.—Forced flexion of the knee for temporary arrest of hæmorrhage in the popliteal space.

Pressure is the ordinary method of hæmostasis used for stopping parenchymatous bleeding. The wound is compressed for a time with aseptic sponges, or, if it occurs in a cavity, the latter is filled with some aseptic dressing material such as iodoform gauze (the wound is packed), or an ordinary dressing is bound on so as to exert pressure.

Packing.—A wound or a bleeding cavity, like the nose or rectum, is "packed" by filling it as tightly as possible with antiseptic dressing materials like iodoform gauze. In hæmorrhage from the rectum, a large square piece of bichloride or iodoform gauze is seized in the centre with the fingers or blunt forceps and pushed up into the rectum in the form of a purse or empty bag, and into this strips of iodoform gauze are forced until the bag is full. The strips or pads of iodoform gauze can be fastened to a string and then packed in place. The col-

peurynter can also be used in the rectum. It consists of a rubber bladder to which a tube is connected, the former being introduced empty into the rectum and then filled by a syringe with warm water or air forced through the tube, which is finally closed by a compression forceps. The elastic bladder works in the same way as the gauze packing.

Cautery.—Of the other methods for hæmostasis the hot iron is the most important, the best form of which is Paquelin's thermocautery (Fig. 57, p. 74) or Middledorpf's galvano-cautery (p. 75). The firm eschar of the burn prevents the escape of blood. The hot iron is usually only suitable for bleeding from small vessels which cannot be ligated. It should be used at not more than a red heat, so as not to burn the tissues too rapidly, but simply to char them slowly.

Styptics.—Amongst the fluid remedies for checking hæmorrhage mention should be made, in the first place, of the liquor ferri sesquichlorati, which makes a firm coagulum with blood. A pledget of cotton or gauze is soaked in it and applied to the bleeding spot as firmly as possible for one or two minutes. This procedure must usually be repeated one, two, or three times. Styptic cotton, as it is called, is simply cotton which has been soaked in liquor ferri sesquichlorati and dried. The material made from the *Boletus igniarius* and the *Penghawar djambi* is very similar to styptic cotton, and consists of the light-brown hairs from the stem of the *Cibotium cuminghii*, an East Indian plant. If this is applied in sufficient amount to the wound surface and with enough pressure, it makes a very good styptic. Noltenius has recommended a penghawar cotton consisting of a mixture of *Penghawar djambi* with cotton and ten per cent. of iodoform. All styptics producing an eschar prevent primary union of the wound. Under fluid hæmostatics there are still to be mentioned vinegar, solutions of alum, turpentine, and aqua Binelli. Wright recommends a solution of fibrin ferment with one per cent. of chloride of lime as a useful hæmostatic, which does not produce an eschar. Cocaine has also a hæmostatic action, and for this purpose can be used in operations on the gums, in bleeding from the nose, etc. For the latter purpose cotton tampons can be used after soaking them in a twenty- to thirty-per-cent. solution of cocaine (also adding a little glycerin). Saint-Germain and Hénocque speak well of the hæmostatic action of antipyrine (either in a twenty-per-cent. solution or in the form of a powder). In cases of hæmorrhage from the genito-urinary tract Meisels has made successful use of cornutin (in doses of 0·01 gramme a day).

Cold and Hot Irrigation.—We arrest capillary and parenchymatous hæmorrhage by pressure applied for a short time, especially by means of aseptic sponges or pads, by irrigation with ice-water, or with water

heated to about 45° C. (113° F.), and by suturing the wound and applying an antiseptic dressing tight enough to exert pressure. Ice-water stops the bleeding by causing the capillaries and smallest vessels, together with the surrounding tissues, to contract, while water at a temperature of about 45° C. (113° F.) acts by directly promoting coagulation of the blood. This explains how cold as well as hot water has a hæmostatic action. As a rule, we employ antiseptic solutions of a medium temperature for irrigation of the wound.

Suture of the Wound.—An important hæmostatic measure, as already mentioned, is the exact coaptation of the edges of the wound by means of sutures, especially in the case of parenchymatous bleeding, and in hæmorrhage from the smaller arteries, particularly those of the skin.

Pressure from Dressings.—The application of an antiseptic dressing which exerts pressure likewise checks or prevents subsequent parenchymatous oozing.

Elevation.—In the case of the extremities we possess a valuable hæmostatic measure in the form of elevation or suspension of the part, and in certain cases, particularly after the use of Esmarch's artificial ischæmia, which is apt at times to be followed by serious parenchymatous bleeding or oozing, this procedure is invaluable.

Fig. 80.—Forceps with a small ligature hook for tying a ligature en masse (Thiersch).

Ligature en Masse.—When large masses of tissue are tied off at once it is not infrequently found that the ligature has not been tied tight enough, and that, moreover, from the manipulation, the fingers become cracked, especially if they come much in contact with carbolic acid; and so Thiersch has recommended that the ligature be threaded through the eye of a "spindle" made of ivory or nickel-plated iron three to four centimetres long. The point of the spindle is rather blunt, so that it can be pushed like a probe through dense masses of connective tissue. This method is especially adapted for the ligation of masses of tissue in ovariotomy, extirpation of the uterus, etc. To prevent injury being inflicted upon the surrounding parts in these operations by sharp-pointed needles, particularly in vaginal extirpation of the uterus, Thiersch has constructed curved, blunt-pointed spindles with an eye for carrying the ligature. The spindle is held in a forceps and thus forced through the tissues (Fig. 80).

Acupressure and Acufilopressure.—Acupressure and acufilopressure (Simpson)—that is, compression of the vessels by long needles stuck through the soft parts (acupressure), or by needles thus inserted and having a thread wound around the projecting ends (acufilopressure)—are at present no longer used and will not be described. Acutorsion has also been abandoned. It

consisted in drawing out the divided extremity of the artery and transfixing it with a needle, which was then given a half or complete turn until the bleeding ceased. After some forty-eight hours the needle was removed.

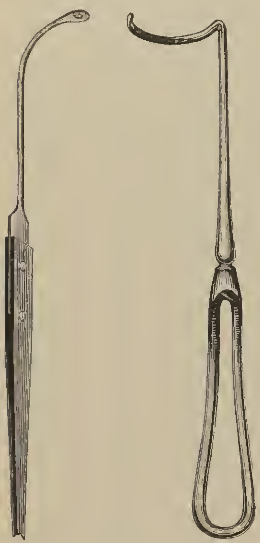
§ 30. **Ligation of Arteries in Continuity.**—The ligation of arteries in their continuity is performed for injuries and for pathological conditions, notably aneurism. In case of severe hæmorrhage from an artery as the result of a punctured, gunshot, or transverse wound, it used to be the custom to ligate the artery at its most accessible portion, in the so-called place of election, proximal to the site of injury. This is not the best plan, on account of the frequency of secondary hæmorrhage from the unsecured wound in the artery after the collateral circulation becomes established. At present we search for the point where the artery has been wounded and tie the vessel on the proximal and distal sides of the wound, and then extirpate the injured portion of the vessel lying between the two ligatures and secure any branches which may be given off in the immediate neighbourhood.

As described under § 18, the ligation of arteries in their continuity is performed as a prophylactic measure, to diminish or control hæmorrhage during an operation upon the region supplied by the artery in question. Under this heading comes, for example, ligation of the lingual arteries in extirpation of the tongue, of the femoral in disarticulation of the femur, of the axillary or subclavian in disarticulation of the humerus. Moreover, the afferent arteries of a part are sometimes ligated to check the growth of an inoperable tumour, and for elephantiasis—for instance, of an extremity, etc.

The operation, which is performed with every aseptic precaution, consists of two parts: (1) The exposure and isolation of the artery, and (2) the application of the ligature. In general it is best to use Esmarch's artificial ischæmia in ligating an artery of an extremity. For instruments we use a medium-sized scalpel, a straight and curved pair of scissors, two toothed thumb forceps, two dissecting forceps, several artery clamps, two retractors, a director, and an aneurism needle, with aseptic silk and catgut ligatures.

After carefully washing the field of operation in the usual way, shaving it, and disinfecting it with a three-per-cent. solution of carbolic acid or of bichloride 1 to 1,000, and placing the part in a convenient position, an incision six to eight centimetres long is made through the skin along the course of the artery. The fingers of the left hand hold the skin firmly stretched, or a fold of skin is lifted up and divided from without inwards, or transfixed and cut from within outwards. The skin is divided by one stroke of the knife. Then the operator and his assistant seize the cellular tissue at two opposite points

with toothed forceps, and while it is gently lifted up it is divided between the two forceps with the knife to the full extent of the cutaneous incision. The remaining tissues are divided as in dissecting until the arterial sheath is reached. The sheath can also be reached very easily and quickly by pushing aside and tearing the tissues with a director, the handle of the knife, or the finger. It is advisable for the beginner to divide the connective tissue carefully upon the director. When the sheath of the artery has been laid bare it is well to make certain, by palpation with the finger tip, that it is the artery which has been exposed. Even though there be no pulsation, one can easily distinguish the firm, thick arterial wall which can be made to roll under the finger from the soft, thin wall of a vein. A nerve feels like a round solid cord. The operator then grasps the sheath of the artery with a fine-toothed forceps or dissecting forceps, lifts it up from the artery, and opens it with a knife or Cooper's scissors or a director. Into the opening thus made in the sheath of the artery is inserted an aneurism needle or curved blunt hook (Fig. 81, *a*, *b*), in order to separate the artery itself on all sides from the sheath. One should never free the artery from its sheath to too great an extent, and one should carry out this step in the operation as gently as possible, to avoid unnecessary laceration of the artery and its sheath. When the entire circumference of the artery has been separated from its sheath, an aneurism needle bearing an aseptic catgut or silk ligature is passed under the vessel, and after encircling the latter the ligature is tied fast around the artery (Fig. 82). Two surgeon's knots supplemented by a simple knot are usually considered necessary for the larger arteries. A surgeon's knot is made by twisting the ends of the ligature twice about each other, and not once, as in forming a simple knot. Large arteries are usually secured by a double ligature, and the vessel is then divided between the central and peripheral ligatures. If an artery is to be tied double—i. e., on the central and peripheral side of



a *b*

FIG. 81.—Aneurism needles.

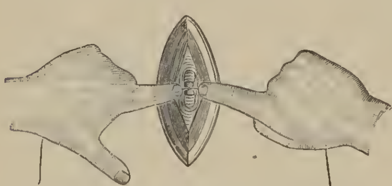


FIG. 82.—Ligation of an artery in its continuity.

the point of injury, perhaps a punctured wound—the aneurism needle is threaded with a doubled ligature, and the latter, after being placed around the artery, is cut at the loop, thus giving one ligature for the central and the other for the peripheral ligation of the artery. In passing the aneurism needle around the artery care must be taken to avoid injury to the neighbouring vein, and before drawing the ligature tight it must be ascertained that the artery alone is tied, and that a nerve is not included in the ligature. After tying the ligature its ends are cut short. If the operation has been performed with the aid of Esmarch's artificial ischæmia, the rubber bandage is now carefully loosened and then slowly removed. When the double ligature has been tied and the intervening wounded portion of the artery has been extirpated, the operator should always look out for branches arising from this intervening portion, which should be secured with the same care as the main vessel, because there is a possibility of secondary hæmorrhage from these branches after the establishment of the collateral circulation. The wound is then drained from its deepest angle, when this is necessary (see § 31), and closed throughout its whole length with a continuous catgut suture, with or without silk tension sutures (page 106). An antiseptic dressing exerting a gentle pressure must then be applied, together with a splint in the case of the extremities, so that the part which has been operated upon is immobilised as completely as possible. Immediately after the artery has been ligated a collateral circulation takes place through the channels formed by the branches given off above and below the ligature (see § 61).

The ligation of particular arteries is taken up in the text-book on special surgery.

The ligation of veins in their continuity is carried out in exactly the same manner as described for arteries.

Ligation of Large Veins.—As a means of checking hæmorrhage from large veins, Langenbeck has recommended ligation of the corresponding artery. In a case of a wound of the common femoral vein made during the extirpation of a tumour, Langenbeck arrested the hæmorrhage by ligating the femoral artery. By ligation of the corresponding artery the amount of blood contained in the part of the body which it supplies is so diminished that the wound in the vein is able to close spontaneously. A simple dressing exerting slight pressure is then sufficient to stop the bleeding. But in other cases the method has entirely failed. It is always safer, when possible, to secure the wounded vein itself.

CHAPTER VII.

DRAINAGE OF WOUNDS.

Importance of drainage.—Different methods of draining a wound: leaving the wound open; aseptic packing; drainage by rubber tubes.—Absorbable drains.—Drainage tubes of glass, metal, etc.—Capillary drainage with strands of catgut, horse-hair, and glass wool.—Formation of openings in the skin.—Secondary suture of Kocher.—Healing under a blood-clot without drainage (Schede).

§ 31. **The Method of allowing the Secretions of a Wound to Escape.—** *Drainage.*—In every fresh wound there is regularly an escape of a bloody, serous fluid, rich in albumin, from the divided tissues, the open capillaries, and lymph spaces, and it corresponds in amount with the size of the wound and the number of cavities and pockets. The formation of these cavities in the wound should be prevented, as far as possible, by sutures and by the application of a dressing exerting proper pressure. By means of the latter we try to promote the agglutination of the more deeply lying tissues which have been divided, and thus to diminish the ensuing secretion—a matter of much importance. In small wounds the pressure exerted by the dressings is sufficient to obtain rapid healing, and it is not necessary to use means for carrying off the secretion except when suppuration is already present, and in the case of large fresh wounds. But if suppuration is present, we must provide suitable channels for the escape of the secretion in the shape of drainage in some form. Unless we do this the secretion is retained in the wound and prevents primary union. Moreover, opportunity is given for the secretion to decompose and for pus to form, and, as a result of the retention of the pus or decomposed secretion of the wound, spreading suppurative inflammation or general infection of the whole system takes place from absorption of the infectious material (pyæmia, septicæmia). The bloody, serous secretion present in the wound, and the blood which has escaped, are highly decomposable, on account of their albuminous character, and consequently it is a matter of great importance to provide careful drainage in large clean wounds and particularly in those which are already infected. At the present time attempts have been made to do away

with drainage in wounds made in aseptic operations, but most surgeons still rely upon it. As a matter of fact, it is indispensable for the first twenty-four to forty-eight hours in large aseptic wounds, even after they have been closed by sutures—for example, after amputation of the breast, accompanied by cleaning out the axilla. The secretion from the wound and the effused blood can thus escape, and so do not prevent the edges of the wound from quickly uniting by primary intention. There are various methods for enabling the secretion from the wound to escape.

The simplest of these is to leave the wound open without suturing it, or only partially suturing it, leaving the angles of the wound unclosed. We combine with this open treatment the sprinkling of the wound with antiseptic powders (iodoform, boric acid, salicylic acid, etc.), or we fill deep wounds or cavities with dressing materials which have a greater or less absorptive power—for example, with strips or wads of iodoform gauze. This aseptic packing of a wound is an excellent method of drainage, as it absorbs the secretion from the wound and causes it to remain aseptic. When necessary, the packing can be fastened in place by sutures through the skin. Wounds which have been left open can then, after a few days, when the packing is removed, be closed by secondary suture, as it is called, which hastens the healing process. Glück has recommended the use of an absorbable aseptic packing, consisting of rigorously disinfected sponges impregnated with iodoform, or a mixture of iodoform, ether, and alcohol, and also skeins or rolls of catgut, and bundles of silk with or without catgut of different shapes and sizes. He recommends their use particularly for intraperitoneal drainage. Catgut alone is absorbable, and therefore only this material can be used as an absorbable packing. The absorbable aseptic packing becomes encapsulated, granulation tissue grows into it, and its place is gradually taken by connective tissue. I do not consider this method desirable.

If we wish to immediately close large and deep wounds, which have not been infected, so as to obtain rapid healing with primary union—i. e., direct agglutination of the tissues without the formation of pus, as in amputations, resection of joints, extirpation of tumours, etc.—we take proper steps for conducting off the secretions of the wound by drains inserted into the deepest portions of the wound.

Drainage Tubes.—The ordinary drains are made of tubes of vulcanised rubber, provided with numerous lateral openings (Fig. 83). These rubber drainage tubes should have as large a calibre as possible, and, while not being too long, they must always be so inserted as to render easy the escape of the secretions from any part of the wound, and

therefore should reach into its deepest portions. Whenever possible, I place the drain to one side of the suture line and not directly beneath it, so as not to separate the suture line from the underlying parts and thus render it impossible for primary union to take place. Drains are passed through a wound with the aid of dressing forceps (Fig. 85) after the skin has been first incised with a knife and the remaining soft parts have been pierced by the forceps. The drainage tube is secured in its position by a stitch taking in a part of the end of the tube, or by a disinfected safety pin, and thns prevented from slipping into the wound. The drain is removed from fresh wounds at the same time that the stitches are, or by the second, third, fourth, or seventh day, according to the nature of the case and the size of the wound. If it is a suppurating wound the drain is taken out when the suppuration ceases, and under such conditions it is best not to remove the drainage altogether at one time, but first to shorten the tubes and then gradually take them out.

FIG. 83. Rubber drain.

FIG. 84. Glass drain.

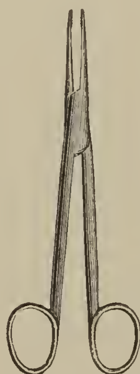


FIG. 85.—Drain forceps.

I have recommended short drainage tubes of large calibre because they do not so easily become plugged up, and consequently there is no necessity for syringing them out with antiseptic solutions. This syringing out of drainage tubes should be avoided, especially in all fresh wounds produced in an operation. It can only do harm by irritating the wound and forcing apart again the already adherent wound surfaces. Even washing out a suppurating wound with antiseptic solutions by means of an irrigator (Fig. 86) is often entirely unnecessary, and may, indeed, do harm.

Absorbable Drainage Tubes.—Besides rubber drainage tubes, other forms have been used, such as absorbable tubes made of decalcified bone (Trendelenburg, Nenber), glass tubes (Fig. 84), silver tubes, tubes made from a coil of wire, etc. The absorbable drainage tubes of decalcified bone have not come into very general use, because they are liable to be absorbed too quickly before they have accomplished their purpose.

Preparation of Absorbable Bone Drains.—Absorbable bone drainage tubes are made as follows: The long, hollow bones of fowls and other birds are freed from soft parts by boiling, and then placed for about ten or twelve

hours in a mixture of one part of hydrochloric acid and two parts of water; the ends of the bones are cut off with scissors and their interior cleaned out with a stout wire, after which they are boiled in a five-per-cent. carbolic solution, to which Deakin adds some borax, and they are finally stored for use in the same solution.

Hardening of Rubber Drains.—To prevent rubber tubes from becoming soft, it is a good plan to harden them by placing them in concentrated sulphuric acid for about five minutes, the larger sizes a little longer; then wash the tubes in seventy-five-per-cent. alcohol and store them in a five-per-cent. carbolic solution or in a 1 to 2 to 1,000 bichloride solution. The orange-red colored rubber tubes are the best adapted to this process, the gray and black not being so good. After the rubber tubes have once been hardened this quality remains unchanged by the fluid in which they are kept stored.

Strands of Catgut as a Drain.—The smallest drain which we use consists of strands of aseptic catgut or horse-hair, which are laid side by side in the form of a bundle of threads. This bundle, for example, of catgut is pushed through a small perforation in the skin, or through the open extremity of the suture line, down into the wound, thus supplying, in small wounds, an excellent form of capillary drainage. Kummel has recommended capillary glass drainage in the form of strands of spun glass.

Attempts have been made to substitute drainage by means of holes made in the skin for the ordinary drainage with rubber tubes in case of wounds directly under the skin, and the canalisation of skin and muscular tissue in case of deeper wounds (Esmarch and Neuber). To make a canal of skin and muscular tissue for purposes of drainage, the cut edge of the skin on each side is attached by a catgut suture to the wound in the muscular tissue beneath it.

Of all these different kinds of drainage, in my judgment the ordinary drainage supplied by rubber or glass tubes, or by packing the wound with sterilised gauze, is by far the best, and all other methods (strands of catgut, bundles of horse-hair, cutaneous punctures, canalisation, and absorbable drains) are only suitable for small wounds, and are insufficient for large, deep wounds in which there are pockets. If the drainage by rubber tubes is properly managed and the drains removed at the right time, it is easy to prevent the evil consequences which the tubes sometimes cause, such as necrosis of the skin, persistent fistulæ, etc. If an operation is performed in a rigorously aseptic manner, with carefully sterilised instruments and hands, and without leaving diseased tissues in the wound, often large wounds made during the operation may be closed without drainage. When this is done it is best to maintain moderate pressure upon the wound by means of the aseptic dressing. It is exceedingly important that the wound should be irritated as

little as possible, and hence antiseptic solutions should only be used when absolutely necessary.

Kocher's Substitute for Drainage.—Kocher has tried to dispense with the drainage of the wound by covering it with a thin layer of subnitrate of bismuth. The latter is sprinkled over the wound in the form of a one-per-cent. mixture of bismuth in water, which is dropped out of a flask ; or, if there is bleeding, compresses impregnated with bismuth are applied to the wound. The wound surface is so much dried up by the bismuth that the secretion is almost *nil.* After twelve, twenty-four, or forty-eight hours the wound is closed by secondary suture.

Schede's Method of healing under a Blood-Clot.—Schede has recently recommended "healing under a moist blood-clot"—e. g., he permits a cavity which has been hollowed out of a bone to fill with blood, closing the wound tight by suturing the skin and not inserting any drain. If the coagulum thus formed in the course of an aseptic operation remains aseptic, it will be gradually absorbed and its place taken by newly formed connective tissue or bone, and healing will occur without reaction. I think this method deserves a fair trial ; it has proved of service to me after operations for caries and necrosis. To prevent the coagulum from becoming too large, I leave the lower angle of the cutaneous wound open. The whole point in Schede's method is the doing away with the drains. As Lauenstein has correctly pointed out, this method is particularly suitable for all wounds with loss of substance in bones and soft parts, but it is not suitable for wounds in which the wound surfaces can be brought into apposition by primary or secondary sutures. Bad results are chiefly due to imperfect asepsis during the operation or after treatment.

CHAPTER VIII.

THE METHOD OF UNITING THE TISSUES.—SUTURE OF THE WOUND.

Disinfection of the wound and surrounding parts before inserting the sutures.—Suture of the soft parts.—Needles, needle-holders, and suture materials.—Different methods of suturing the wound (interrupted, continuous, silver-wire suture, plate suture, twisted suture).—Removal of the sutures.—Secondary suture.—Bloodless suture.—Subcutaneous suture of nerves, tendons, muscles, etc.—Union of wound surfaces in bones (bone suture).—Periosteal suture.—Nailing and other methods of uniting the surfaces of a divided bone.

§ 32. **Disinfection of the Wound before inserting the Sutures.**—After arresting the hæmorrhage very carefully and putting in the proper drainage, the wound and the surrounding parts are washed with a three-per-cent. solution of carbolic acid or 1 to 1,000–5,000 solution of bichloride of mercury. The irrigator (Fig. 86) is best suited for this purpose ; it is made of metal—or, better, of glass—with a rubber tube provided with a removable tip made of glass or rubber, through which the solution flows. A warning must be given against too vigorous cleansing of the wound with antiseptics—excepting in the case of already infected wounds—because too much irritation is produced, and the ensuing secretion from the wound will be increased. I irrigate wounds made during an operation only in those cases in which there is the possibility of infection having occurred during the operation. In wounds already infected and when pus is present, etc., fairly strong antiseptic solutions should be employed (four-to-five-per-cent. carbolic or 1 to 1,000 bichloride), but the weaker antiseptic solutions should be used at the end to again remove from the wound the concentrated and more or less caustic solutions which may easily produce symptoms of poisoning. If there are no irrigators at hand, clean, well-

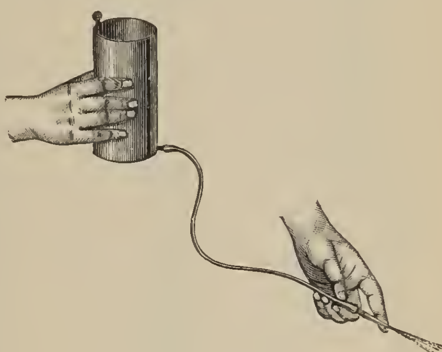


FIG. 86.—Irrigator.

disinfected sponges, or aseptic gauze, or cotton tampons, may be soaked full of the antiseptic fluid, which is then squeezed out over the wound and adjoining parts, thus cleansing them. I use antiseptic solutions as little as possible, and avoid irrigating the wound with them after the operation, as the secretion from the wound is much less if the irrigation with irritant solutions is omitted. The main point is always to operate with perfectly aseptic hands and instruments. When the hæmorrhage has been arrested and the wound treated on these general principles, we proceed to insert the sutures.

§ 33. **The Uniting of the Soft Parts—Suture of the Wound.**—In all cases in which we wish to obtain as speedy union of the wound as possible (*per primam intentionem*) we close the wound by suturing together its edges. Suturing should always be carried out with the same regard to asepsis as was had in the operation itself, and hence the needles and the sutures must be previously made aseptic.

For introducing sutures we use straight and variously curved needles with lance-shaped points. I use straight lance-shaped needles almost exclusively for the skin. Curved needles are suited particularly for deeply lying portions of the body and for introducing sutures in

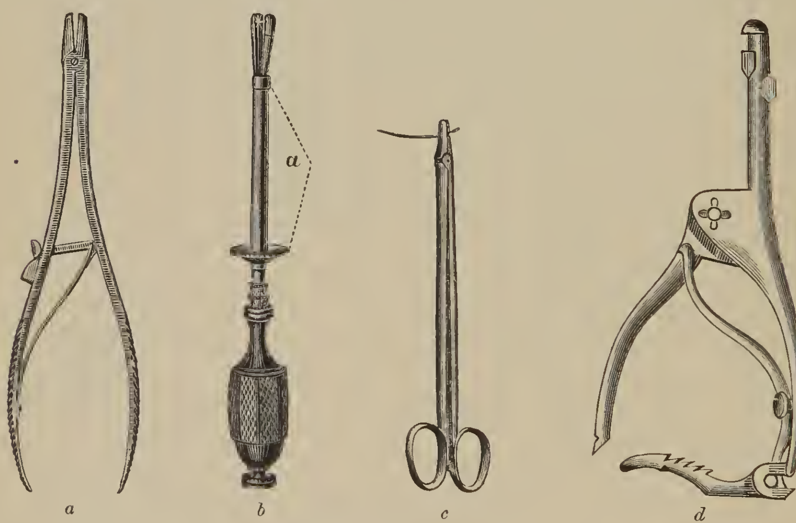


FIG. 87.—Needle holders.

cavities (mouth, gums, throat, vagina, etc.). Hagedorn's needles, which are flattened on the sides, are very useful. The recently introduced platinum-iris needles possess the advantage of not oxidising, and they can be heated red-hot without losing their original temper. Besides the ordinary needles without handles, there are many provided with

handles, though I never use them. When the needle cannot be introduced by hand, as in the mouth or pharynx, the vagina, etc., we use a needle-holder. Of the numerous different kinds of needle-holders, those worthy of mention are the holders of Dieffenbach, Reiner (Fig. 87, *a*), Roux (Fig. 87, *b*), and Sims (Fig. 87, *c*). Hagedorn has recently invented a most excellent needle-holder, which I now use exclusively (Fig. 87, *d*).

Suture Material.—Sutures are made of sterilised silk impregnated with carbolic acid or bichloride of mercury, of linen thread, catgut, horse-hair, sea-grass, silkworm gut (from the chrysalis of the silkworm), crin de Florence (from the intestine of the silkworm), and silver wire. Catgut has the great advantage over silk that it is absorbable, and is therefore preferable for subcutaneous or buried sutures—that is, suture of nerves, tendons, muscles, etc. Moreover, buried catgut sutures are the best for uniting a ruptured perinæum; for the radical cure of hernia; for operations on the uterus, bladder, or intestine; and for operations on fistulæ. If catgut is used for suturing the skin, the sutures will not need to be removed with scissors, but after about four to seven days the external portion lying over the line of the wound can be simply picked off with forceps, as the part which lies buried in the tissues is absorbed, or is only very weakly attached to the rest of the suture. On account of this rapid absorption of catgut, it follows that under certain conditions catgut sutures will not hold the borders of the wound long enough in apposition, and so I do not use catgut alone for suturing the skin, but combine it with aseptic silk, especially if the skin is under considerable tension. The preparation of a satisfactory catgut has been described on page 88. The size of the catgut or silk suture required will, of course, depend upon the kind of tissues to be united and the amount of tension. When there is great tension strong sutures are naturally required, because fine sutures would easily cut through.

Silver wire should be made smooth before use by passing it through a flame till it becomes red-hot. Silkworm gut is excellent for tying off the pedicle in ovariotomy, for perineal operations, etc. In the place of expensive silk, Trendelenburg and Heyder recommend linen thread for ligatures and sutures. It is cheap, and easily obtained at any time (even in war).

Sutures made from the Tendons of Reindeer, Horses, and Deer.—Ratiloff uses the tendons of reindeer for suturing wounds. This material is used by the Siberian colonists for sewing. Putilow uses the tendons of horses and deer. The strips of tendon are soaked for twenty-four hours in ether, and for the same length of time in a five-per-cent. alcoholic solution of carbolic

acid. The strips of tendon thus prepared are said to be stronger than catgut, as soft as silk, and completely absorbed in the wound.

The Interrupted Suture.—The most common form of suture is the so-called interrupted suture (Fig. 88). This is introduced with straight or curved needles, the aseptic catgut or silk being simply knotted in the eye of the needle, or, better, threaded so as to leave two long ends. The knot, especially if the suture is of large size, interferes with drawing the eye portion of the needle through the skin. The border of the wound is seized with a toothed forceps, and the needle is pushed through first one edge of the wound and then the other. Both edges of the wound can be pierced at the same time, provided they are held together by an assistant. The knots should be placed to one side of the line of suture. If there is much tension on the edges of the wound the so-called surgeon's knot is occasionally used—that is, the ends of the suture are twisted not once, but twice about each other. It is best to begin the suture not at the ends of the wound, but in the middle, especially if it is a long one; and at the time of inserting the first suture care should be taken to have the borders of the wound in good apposition, as otherwise troublesome folds at the extremities of the line of suture may result.

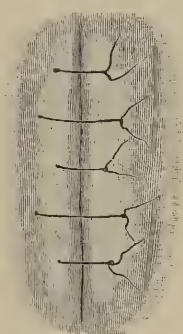


Fig. 88.—Interrupted suture.

Two different kinds of sutures are classed under the head of interrupted sutures—the tension suture and the coaptation suture. The first is inserted and brought out anywhere from 1–2 to 4–6 centimetres from the edges of the wound, whilst the second or coaptation suture is shorter, and the points where it enters and emerges are only about half a centimetre distant from the edges of the wound (Fig. 88).

Those sutures by which correct apposition of the borders of a long wound are obtained are called apposition sutures. In every suture line the greatest care is necessary to prevent the edges of the wound from becoming inverted, and the two borders must lie in good apposition with each other. The sutures must not be drawn too tight. It must constantly be borne in mind that the successful healing of a sutured wound depends upon the proper insertion of the sutures, and that sutures applied unskilfully and without antiseptic precautions may give rise to serious dangers. An erysipelas which may cause the death of the patient may start from a small spot of necrosis in the skin, arising, perhaps, from a portion of the border of the wound which has got turned in, if the borders of the wound are not properly placed in apposition; or it may start from a small stitch abscess produced by an

imperfectly disinfected needle or suture. Tremendous results may follow from very small causes. Furthermore, no appreciable cavity should be allowed to remain; and hence the deeper-lying parts are sometimes united by special catgut sutures or are included in the cutaneous sutures. "Good sutures, good results," was a favourite saying of Nussbaum.

Continuous Suture.—Instead of the ordinary interrupted suture I frequently use the continuous suture, and usually in combination with tension sutures (Fig. 89). I use, whenever it is possible, needles with lance-shaped points, of the same size as the ordinary tailors' needles. The fine suture, which should not be too long, is simply knotted in the eye of the needle. The number of tension sutures required depends, of course, upon the length of the wound. The tension sutures are inserted in the usual way, and then the continuous suture is begun at one end of the wound by making one ordinary interrupted suture; the thread, however, is not cut, but the suture is continued by transfixing at equal distances the opposed borders of the wound, which are held together by the fingers. When the other end of the wound is reached (Fig. 89, *a*) the suture is cut with scissors, and the three threads are knotted together like the ordinary interrupted suture, two threads being on one side of the wound and one upon the other. The suture can also be finished off by forming a loop through which the extremity of the suture is drawn. The continuous suture has the advantage over every other kind of being capable of very rapid execution, and of rendering excellent coaptation of the borders of the wound. If the wound is very long and there is fear that a single continuous suture will not be strong enough, the suture can be interrupted at any desired part of the wound, and from this point a fresh continuous suture can be begun; or it can be given greater security by tying it at any point and then continuing. But when the precaution of inserting tension sutures is taken there need be no fear that the continuous suture will prove at all untrustworthy if it is carefully inserted. Catgut is ordinarily the best material for the continuous suture, and I use aseptic silk for the tension sutures. The continuous suture is particularly adapted for operations on the peritonæum and the gastro-

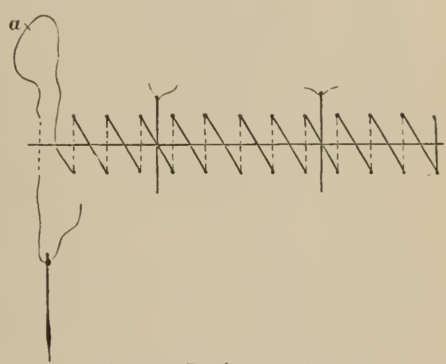


Fig. 89.—Continuous suture.

intestinal tract, and for the buried catgut suture in operations on the vagina for prolapse and for rupture of the perinæum.

Silver-wire Sutures.—If silver wire is used for suturing, it is fastened to a straight or curved needle by simply bending over one end of the wire after it is threaded through the eye. The silver-wire suture is fastened in place by exerting suitable traction on the wire and then simply twisting together its crossed ends, or an instrument particularly designed for the purpose may be used (Fig. 90). The cross-piece of the "wire twister" contains two round openings into which the ends of the wire are passed after they have been crossed over the wound, and then by rotating the instrument the wires are twisted around each other.

Fig. 90. Wire suture tightener.

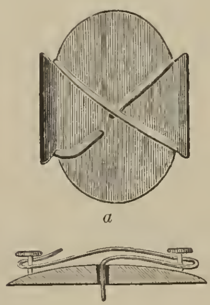


Fig. 91. Lead plates.

The Silver-wire Suture with the Lead Plate.—A form of tension suture which has at present somewhat gone out of use is the silver-wire lead-plate suture used for closing the wound after abdominal section or amputation of the breast. Small lead or glass plates are required which are perforated in the centre. The silver wire is either twisted around the plate (as in Fig. 91, *a*), or fastened to pins on its surface (Fig. 91, *b*), or else the silver wire is inserted in a small lead ring which is pinched together with forceps. Glass beads can also be used. The end of the wire is passed twice through the bead and drawn tight, then through the lead plate, and after attaching it to a needle the suture is inserted. Upon the other side of the wound the wire is first passed through the lead plate, then through one or more glass beads, and after obtaining the proper tension the wire is twisted around a sterilised match and the ends are cut short with scissors. It is a very good plan to use, instead of silver wire, a double silk suture having each end so fastened together over a glass bead that only one and not both threads pass through the bead. Pledgets of iodoform gauze can also be used for securing the ends of the silver-wire lead-plate suture. At present I have given up this kind of suture, and prefer a tension suture of stout sterilised silk inserted some distance from the edge of the wound. The latter, furthermore, is more quickly inserted.

Other Methods of Suturing.—The old-fashioned continuous furrier's stitch, the fin stitch, and the looped suture are useless and out of date, and will not be described. The continuous suture which I have described differs materially from the continuous furrier's stitch. The so-called "figure-of-8" or twisted suture (Fig. 92) I also consider unnecessary, and no longer use it. The interrupted suture answers the same purpose, and is more simply inserted and is better for the tissues. It is applied in the following way: The edges of the wound are transfixed by long Carlsbad needles some distance apart. About the ends of the needles is twisted an aseptic silk suture in the

form of a circle or figure of 8, and the extremities of the thread are knotted together. The sharp ends of the needle are clipped off with a Luer's rongeur forceps.

Deep Sutures attached to Beads.—Thiersch's method of inserting deep sutures with their ends attached to beads—for example, into the rectum or vagina—is a very good one. To the end of the silver wire a bead is fastened, as in the plate suture; a lead plate is then placed next on the wire, the other end of which is threaded on a needle and passed through the borders of the wound. After removing the needle, the needle end of the wire is passed through ten to twenty glass beads and secured by pinching together a piece of lead upon it; by pushing the lead up or down on the beads the suture can be loosened or tightened. To remove the suture, the wire is cut on the proximal side of the piece of lead and pulled out by drawing on the other end.

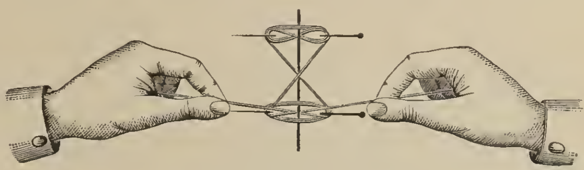


Fig. 92.—Figure-of-8 suture.

The Removal of Sutures.—The stitches are taken out, in the majority of cases, at any time from the third to the seventh day, according to the kind of wound. We frequently—for instance, after plastic operations on the face—take out a stitch here and there at the end of twenty-four hours; but in other cases, on the contrary, as when the peritoneal cavity has been opened, we allow the stitches to remain till the eighth to the fourteenth day. In long wounds, and in those in which there is danger of the agglutinated borders of the wound separating after removal of the sutures, the latter should not all be taken out at the same time. The tension sutures, particularly at the extremities of the wound, when combined with the continuous suture, should be taken out first. If the tension sutures become buried in the skin—i. e., "cut out"—they should be removed immediately. Sutures are removed by seizing one end of the knot with dissecting forceps and, while slight traction is exerted, cutting off the suture close to the wound and carefully drawing it out. Care must be taken that the whole suture is removed. If catgut has been used it is unnecessary to cut the stitches with scissors, as the portion buried in the tissues is absorbed, and only leaves the exposed loop of catgut to be picked off the skin with thumb forceps.

Secondary Suture.—If the borders of the wound gape after removal of the stitches, the wound can be reunited by a fresh suture (secondary suture). This secondary suture is very much used—for example, in wounds which have been first packed, or in wounds which have been

left entirely open during the first few days, or in deep, granulating wounds, etc. To avoid a repetition of the anæsthesia when secondary sutures are applied, Nussbaum has advised that the secondary suture be put in place at the time of the first operation. For example, a mattress or continuous suture should be inserted in advance in each margin of the wound, and then, later, the loops of these sutures can be used to close the wound by passing a silk thread through them.

Bloodless Suture.—Besides the above-described kinds of suture there is a bloodless or dry method of suture. The Arabs used, for closing a wound, an insect (*Scarites pyræmon*) whose maxilla terminated in a small hook. The borders of the wound were approximated by these hooks, the body of the insect being removed and leaving only the head with its hooks. Vidal de Cassis attempted to imitate this method of approximation with his *serre-fine.* This instrument is usually made of a round wire fashioned so as to have jaws closing by a spring, which are opened by pressure behind the point where the jaws cross. It has passed out of use, very properly, as the method is painful and unreliable.

The suture of tendons, nerves, etc., is described in the third section (§ 88, Injuries, Wounds), and suture of the intestine, bladder, etc., is treated of in the text-book on special surgery.

§ 34. **The Method of uniting Wound Surfaces of Bone.**—The surfaces of a wound in a bone can be held in apposition by periosteal sutures only when small bones are concerned. A suture passed through the bone itself is, of course, the best. The necessary holes are made in the bone by drills (Fig. 93) worked by pushing the wood or metal spool on the instrument up and down, and thus causing the needle attached to the instrument to rotate. Silver wire, which is allowed to remain in the wound, or stout catgut, are used as suture materials. J. Henequin (Rev. de Chir., August, 1892) and V. Wille (Centrbl. für Chir., 1892, p. 46) have recommended a very good method of bone suture. Wille's plan consists in boring a hole through both walls of a hollow bone and dragging the silver wire through it by means of a peculiar "suture hook."

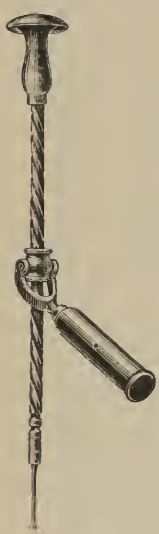


Fig. 93.—Drill for bone sutures.

Another excellent method of uniting the surfaces of a wound in bone is aseptic nailing. Long, four-cornered nails are used, which are first very carefully polished and then disinfected in a five-per-cent. carbolic-acid solution, after which they are placed in absolute alcohol and finally heated red-hot in the flame of a spirit lamp. After some three or four weeks

the loosened nails can be easily drawn out with forceps or the fingers and without causing the patient pain. Of course, care must be taken that the nails project at least two centimetres beyond the level of the skin. Long ivory pegs are sometimes used instead of metal nails; but I have found that ivory pegs are not so easily removed as iron nails, as the outer surface becomes rough from contact with the tissues, especially bone. The ivory pegs become decalcified by the action of the carbonic acid in the tissues, and the remaining organic portion is dissolved, thus producing small pockets and cavities into which the surrounding bone grows. The aseptic nailing together of the surfaces of a wound in bone, as after resections, particularly of the knee and ankle, in fractures, separation of the epiphyses, etc., is entirely devoid of danger if the operation is performed with the strictest antiseptic precautions.

For fastening together a divided bone, as in separation of the epiphysis at the upper end of the humerus, Helferich has recommended long, awl-like steel needles, fitted with a handle which unscrews. These are made to slowly bore their way into the bone. After eight to fourteen days the needles are removed.

A clamp apparatus has been recommended for uniting the surfaces of a bone wound. Under fractures we shall become acquainted with Malgaigne's hooks and Langenbeck's screw. In cases of fracture Bircher has recently introduced the practice of inserting an ivory peg into the open ends of the medullary cavity of the diaphysis, and of using ivory clamps for holding in contact fractures involving the epiphyses. In part of the cases the wound healed up over the ivory peg; in sixteen cases (out of thirty-five) the peg had to be subsequently extracted.

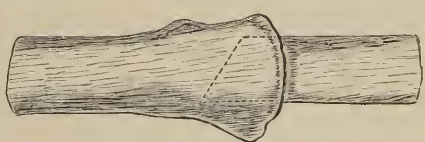


Fig. 94.—Union of the ends of bones by implantation.

Another method of uniting a wound in bone is illustrated in Fig. 94. The somewhat pointed extremity of one fragment (the femur) is inserted, for instance after resection of the knee, into the medullary cavity of the other fragment of bone (in this case the tibia).

Formation of Periosteal Flaps and Transplantation of Cartilage and Bone in Cases of Loss of Substance in Bone.—Loss of substance in bone can be remedied by periosteal flaps (Nussbaum) or by the transplantation of cartilage or pieces of bone from young animals (rabbits and dogs). Gluck has attempted to supply loss of substance in bone by the implantation of dead bone and ivory (see § 101, Treatment of Fractures—Osteoplastic Method). The suture of bone or the holding of the

surfaces of a divided bone in apposition by one of these methods is especially indicated in compound fractures—for example, in compound transverse fracture of the patella or olecranon, in fractures of the lower jaw, etc. Besides these, it is indicated in resections of joints, such as the knee, in resections of bones in their continuity, after temporary division of bone, and in complicated harelip operations, etc.

CHAPTER IX.

AMPUTATIONS, DISARTICULATIONS, AND RESECTIONS.—GENERAL CONSIDERATIONS.

Performance of amputations and disarticulations.—Subperiosteal amputations and disarticulations.—History of the methods of amputations and disarticulations.—After treatment.—Bad sequelæ.—Infection of the wound.—Muscular spasm.—Secondary hæmorrhage.—Gangrene of the flaps.—Necrosis of the stump of the bone.—Conical stump.—Neuralgia.—Neuromata.—Fatal results.—Mortality statistics.—Artificial limbs.—The methods of performing resection.

§ 35. **General Considerations in performing Amputations and Disarticulations.**—By *amputation* (from *amputare*, to cut off) is understood the operative removal of an entire portion of an extremity. If a limb is severed through a joint the operation is called a disarticulation, in contradistinction to amputation, in which the portion of the limb removed is cut off by sawing through the bone in its continuity. Amputation is not confined to the extremities alone, but is used to designate the removal of certain portions of the trunk, like amputation of the breast, the penis, or the portio vaginalis. We shall discuss here only amputations and disarticulations of the extremities.

The Indications for Amputations and Disarticulations have markedly decreased in modern surgery, which leans more and more towards conservative methods of treatment. With the aid of the antiseptic method we are now often able to save a limb which formerly, in the preantiseptic era, would have fallen a prey to the mutilating effects of amputation and disarticulation. We shall entirely omit a detailed description at this point of the indications for amputation and disarticulation, as there will be opportunity enough for discussing this subject when we take up special diseases and injuries. It is sufficient to state here that these operations are indicated in all diseases and injuries of the extremities which threaten to destroy the whole limb or the life of the patient, and hence in (1) extensive injury to the soft parts and bone which precludes the possibility of saving the extremity in question, or renders the physical condition of the patient such that he cannot withstand a long confinement to bed, or in consequence of which the extremity, if

spared, would be useless; or (2) in extensive inflammation or disease of the extremity which would render it completely incapable of performing its functions, or which threatens the life of the patient. Under the latter heading come extensive gangrene, malignant new growths, irreparable injuries to bones and joints, large ulcers, spreading (septic) intermuscular suppuration with threatening systemic infection, etc. Under the separate injuries and diseases we shall refer again to the indications for amputation and disarticulation. At present the general suggestions just made will be sufficient.

When an *amputation* and when a *disarticulation* should be performed are questions which in general depend upon the nature of the case in hand and the location of the injury or disease. We shall discuss this more fully in the Special Surgery. Formerly, in the preantiseptic days, disarticulation was performed more frequently, as it dispensed with the dreaded opening of the medullary cavity. In fact, there were surgeons who went so far as to give up amputations for this reason and performed only disarticulations. Since the introduction of the aseptic method of operating this consideration is no longer thought of. At present the question whether amputation or disarticulation is better for any particular case is usually decided by practical considerations. Both forms of operation are practiced, and amputation or disarticulation is decided upon according to the circumstances in each individual case. In general, amputations are performed much more frequently than disarticulations, because the former can be carried out at any part of the extremity, while the latter are confined to the joints.

The method of dividing the soft parts, particularly the skin, is practically the same in both operations. The soft parts must be divided in such a way as to form a good covering for the bone stump. We distinguish three principal forms of incision—(1) the circular, (2) the flap, and (3) the racket-shaped incision.

§ 36. **General Considerations in regard to Amputations.**—The field of operation is carefully cleaned throughout its whole extent with soap and a brush, shaved, and then disinfected with a three- to five-per-cent. solution of carbolic acid or 1 to 1,000 bichloride. The patient is placed in a convenient position, and a particular duty is assigned to each assistant. The operator stands so that the limb to be operated upon will fall to his right. We operate in all cases, if possible, with the assistance of Esmarch's artificial ischæmia, described in § 19. During the operation all the rules of antisepsis must be strictly observed by the operator and his assistants; no unclean finger or instrument should come in contact with the wound. The knife as well as the saw

should be used carefully and gently, and pains should be taken not to bear down too hard on the instruments. Violent manipulation and compression of the soft parts are to be avoided, as well as too vigorous rubbing of the wound with sponges or compresses. In fact, sponging can be almost entirely dispensed with when Esmarch's artificial ischæmia is used.

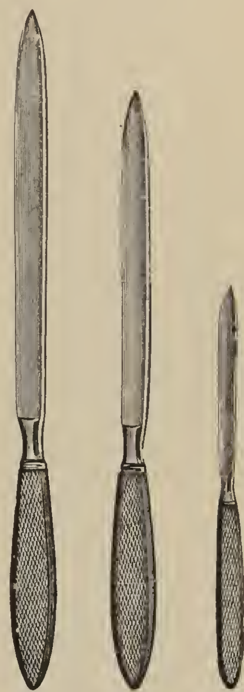


Fig. 95.—Amputation knives.

I. **Circular Division of the Soft Parts in a Single Stroke** (Celsus, Louis).—The soft parts, having been drawn up by the hands of an assistant, are divided circularly down to the bone by a single stroke of the amputation knife (Fig. 95) held at right angles to the axis of the limb (Fig. 96). The size of the amputating knife should depend upon the diameter of the limb. The amputating knife is grasped in the closed fist, the hand passed under the limb, and the incision is begun with the part of the edge nearest the handle, which is placed on that portion of the surface of the limb which faces the operator (Fig. 96). The blade is then drawn around the entire circumference of the limb, dividing all the soft parts down to the bone. I think it is easier and better to begin the incision with the knife in the right-angled position, point upwards, on the side of the limb which faces away from the operator. The knife is then carried with a sawing motion around about two thirds of the circumference of the limb, dividing all the soft parts down to the bone. Starting from the beginning of this incision, the knife is carried in the reverse direction, dividing the soft parts on the side of the limb facing the operator. After division of the soft parts the bone is sawed through. Then the cylinder of soft parts is drawn up on the bone stump by an assistant, while the

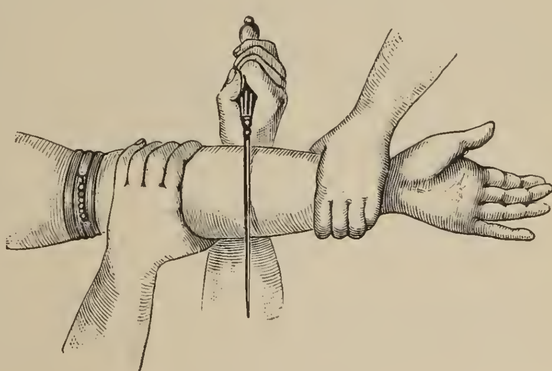


Fig. 96.—Circular method.

operator grasps the extremity of the bone stump with Luer's or Langenbeck's bone forceps (Figs. 67, *d*, and 68), and elevates or pushes back the periosteum by means of a periosteal elevator (raspatory, Fig. 63) a distance equal to about half the diameter of the limb. At this point the bone is again sawed through, thus allowing the cylinder of soft parts to completely cover the stump of bone and the edges of the skin to be united, usually in a transverse line, without tension on the sutures. In amputations of extremities containing two bones, such as the leg, the forearm, the metacarpus and metatarsus, the muscles and soft parts lying between the bones must be divided before sawing the bones. For this purpose a small, pointed, double-edged knife, sometimes called a catline, is best (Fig. 97). This knife is inserted in the space between the bones and the soft parts divided by cutting first with one edge against one of the bones and then with the other edge against the other bone. This procedure is then repeated by inserting the knife from the opposite side into the space between the bones. Instead of the two-edged knife, a small scalpel can be used for this purpose. After dividing the soft parts in the space between the bones and laying the bones free, the latter are sawed in such a way that the division of both is completed at the same time. Thus, in amputations of the leg the tibia is first sawed about three quarters through before one begins to saw the fibula, and then both are completely sawed through at the same time.

Fig. 97. Catline.

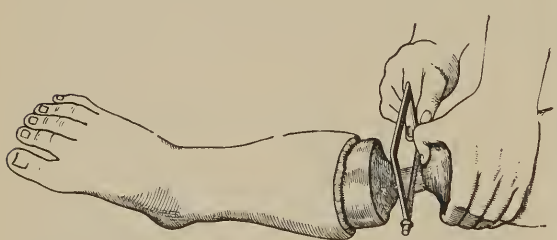


Fig. 98.—Division of a bone by the saw.

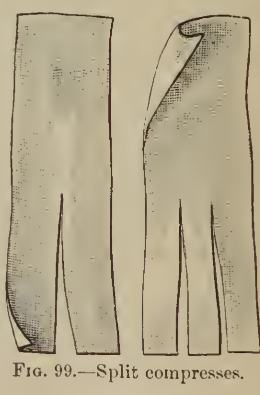


Fig. 99.—Split compresses.

For sawing the bones in amputations it is best to use the bow-saw (see page 83, Fig. 70, *b*, *c*) in the way illustrated in Fig. 98—i. e., the saw is placed close to the soft parts, at right angles to the thumb of the left hand, which is placed upon them. To prevent injury to

the soft parts they are retracted by a split aseptic compress (Fig. 99) or the hand of an assistant. The distal portion of the limb is held by an assistant, and allowed to drop a little as the sawing progresses, so that the saw does not become jammed. If projecting spicules of bone remain after the sawing is completed they must be cut or smoothed off by bone shears or forceps, or the metacarpal saw or chisel may be used for this purpose, as for removing the anterior projecting border of the tibia.

After amputation by the ordinary circular division of the soft parts three drainage tubes are generally inserted—one at each angle of the wound, and one in the centre of the posterior skin flap; but in small stumps the latter drain alone is sufficient. A continuous catgut suture with several interrupted silk tension sutures should be used to close the wound.

Modifications of the Circular Division of Soft Parts in One Sweep.—After cutting the soft parts circularly in one sweep down to the bone, as just described, the cylinder of soft parts is drawn up or retracted by an assistant. The muscular fibres still adhering to the bone cause the surface of the wound to have the shape of a cone. A knife is then carried circularly through the base of this cone down to the bone at the point where the latter is to be divided. If the covering for the bone stump thus made out of the soft parts is not sufficient, the muscles are then freed from the bone by a scalpel. The bone can then be sawn through with or without first elevating the periosteum. By this method the surface of the relaxed wound is made to assume the shape of a short, hollow cone with its apex towards the trunk.

The division of the soft parts in the form of a cone can be omitted, and the muscles simply freed from around the bone by means of a small scalpel and retracted by the fingers of the left hand.

The Elevation of the Periosteum.—It is not always necessary to elevate the periosteum from the bone before sawing it through. I usually omit it. According to my experience, the bone-forming power of the elevated periosteum does not affect the subsequent condition of the stump.

On account of the rapidity with which it could be done, the circular method, performed with one sweep, used to be much employed when operations were carried out without anæsthesia, but at the present time it is less often used. In fact, it is little suited for extremities having powerful muscles, for it provides a more or less insufficient covering of soft parts and of skin for the bone stump, and therefore is conducive to the formation of the so-called conical stump. But, on the other hand, this method is a perfectly proper one for performing

amputations on children and thin subjects, particularly in the case of limbs containing only one bone.

II. **Circular Method of dividing the Soft Parts at Two Different Levels.**—An incision is carried circularly around the limb through the skin down to the fascia. The skin is then drawn up by an assistant, while it is freed from the subjacent parts by carrying a knife, held at right angles to the axis of the limb, circularly around the latter at the edge of the skin, cutting down to the fascia (Fig. 100), or by dissecting the skin and subcutaneous tissue from the deeper tissues by means of a scalpel. When the skin has been thus sufficiently freed from the fascia it is turned back in the form of a cuff, the length of which should equal about half the diameter of the limb. A circular incision through all the soft parts down to the bone is then made close to the attached edge of the cutaneous cuff, and the bone is then sawed in the manner already described. Here also it is a good plan to separate the muscular insertions from the bone for a short distance to insure a sufficient covering for the stump.

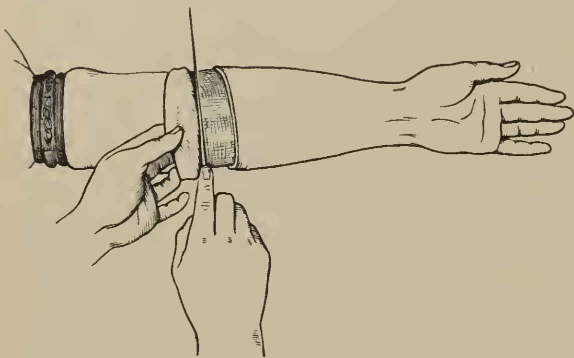


Fig. 100.—Formation of a cutaneous cuff in a circular amputation at two levels.

Funnel-shaped Method.—The so-called funnel-shaped method of dividing the soft parts (Alanson) is only a modification of the method just described. The skin is first divided circularly, and the knife is then applied at the margin of the retracted skin, having its edge directed obliquely upwards and at the same time towards the bone, in which direction it is carried through the muscles down to the bone. In this way a conical-shaped wound surface is made, with its apex towards the upper end of the bone.

III. **The Flap Methods.**—The flap methods vary in the thickness, shape, and length of the flaps.

At the present time flaps are generally made to consist only of skin, or skin and subcutaneous tissue, as it is well known that the muscles in the flap covering the bone stump subsequently disappear entirely by fatty degeneration. But it is an excellent plan to fashion flaps of both cutaneous and muscular tissue whenever the skin is very thin and badly

nourished. The shape and position of the flaps vary very much, though anterior and posterior flaps are usually made either of equal length, or a long anterior and short posterior flap are made, in order that the suture line shall come to lie more posteriorly.

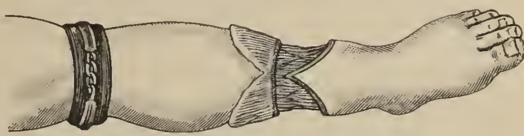


FIG. 101.—Formation of two semilunar skin flaps.

The incision for the cutaneous flaps may be made in the same way as in the circular method of amputating in two stages just described, and then longitudinal incisions some five or six centimetres long are made on the inner and outer aspect of the extremity, thus forming two cutaneous flaps of equal length, an anterior and a posterior. These are then freed from the fascia and turned back. The muscles are divided at the point where the cutaneous flaps are turned back, just as in the circular method of amputating in two stages. Another way is to form two semilunar-shaped skin flaps, either in front and behind or laterally, using a large scalpel with a blade convex on the edge. The flaps of skin are dissected from the fascia and turned back (Fig. 101).

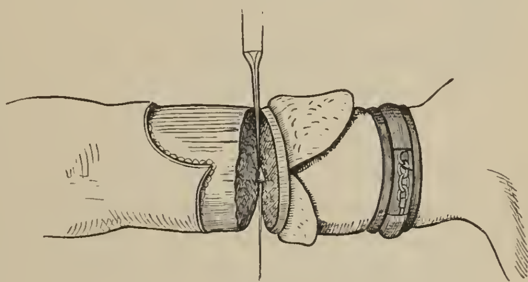


FIG. 102.—Formation of a large anterior and small posterior skin flap.

It is a very good plan to make a long, semilunar-shaped anterior flap of skin with a small posterior flap (Fig. 102). The former must be long enough to cover the entire cut surface like a curtain. The overhanging anterior flap is made in the

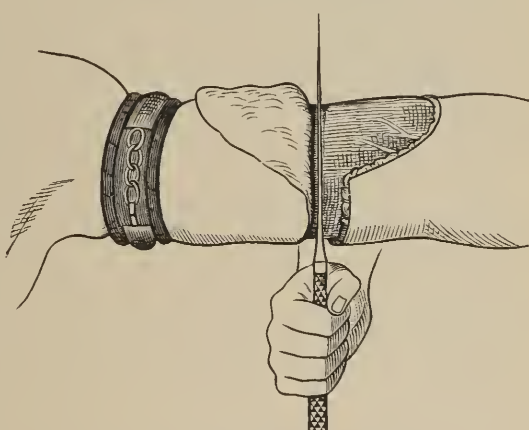


FIG. 103.—Anterior overhanging flap, and posterior semicircular incision.

simplest way, by cutting an anterior semilunar-shaped cutaneous flap and freeing it from the subjacent parts. The base of the flap should be equal to about half the circumference of the limb, and its length should equal its sagittal diameter. A similar but smaller cutaneous flap is then cut from the posterior half of the circumference of the limb and dissected from the fascia.

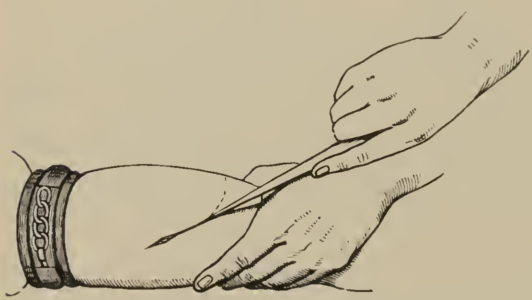


Fig. 104.—Formation of a flap of skin and muscle by an incision from without inwards.

A very simple way of carrying out this method of amputation by a long anterior flap, after the latter has been cut and turned back, is to divide the skin on the posterior portion of the circumference of the limb by a single circular sweep of the knife. The posterior flap is then dissected back from below upwards, as usual, by strokes of the knife held at right angles to the axis of the limb, and the muscles are then cut circularly by a single sweep of the knife (Fig. 103).

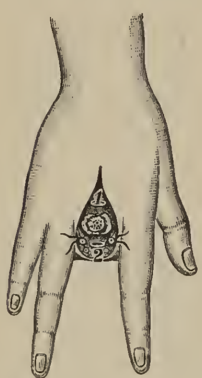


Fig. 105.—Disarticulation of the middle finger: 1, extensor tendon; 2, flexor tendon and near by the two ligated digital arteries and the nerves. In the center of the wound is seen the articular surface of the metacarpus.

Some surgeons prefer to include the fascia in the skin flaps, freeing skin and fascia together from the underlying muscles, as they believe that the skin flaps are better nourished in this way by the extensive network of vessels lying between the skin and fascia, particularly if the portion of skin in question is loosely attached and thin. I do not like these flaps of combined skin and fascia, and agree with Oberst that the fascia, on account of its poor blood supply, especially if the conditions for circulation are unfavorable, is liable to necrose and so interfere with primary union. I think it better to form cutaneous flaps without the fascia. If the skin is not suitable for making flaps on account of being too thin, I prefer the circular method of amputation, carrying the knife to the bone in one sweep, or the method in which the flaps include both skin and muscular tissue.

The formation of flaps consisting of both skin and muscular tissue is not at present so much in vogue as formerly. The wound surface

is too large, the flaps are too heavy, and the vessels are usually cut obliquely. These flaps are formed either by cutting from without inwards (Fig. 104), or in the reverse direction, from within outwards, by means of transfixion. In the latter method a double-edged knife is inserted close to the bone, at the base of the flap to be formed; then the knife is carried with a sawing motion obliquely downwards and outwards. All transfixion methods are bad, because the vessels are often wounded or divided in two different places. It was formerly used very often, when operations had to be performed rapidly without anæsthesia.

IV. **The Oval or Racket Incision** (Fig. 105).—This is a compromise between the single circular sweep of the knife and the flap method. It is chiefly used for disarticulating fingers and toes, but it is seldom made use of in amputating. It is really an obliquely placed circular amputation—i. e., two lateral incisions are made, which meet at a sharp upward angle on the back of the limb, and in a slight downward curve on the front.

The Treatment of Amputation Wounds.—Hæmorrhage after amputation is arrested by seizing separately all the divided vessels, both arteries and veins, in the bloodless stump with self-locking hæmostatic clamps and then ligating them with catgut or aseptic silk (Fig. 106). To find the small muscular branches in the surface of the bloodless stump, one should follow the muscular interspaces, where the vessels can be discovered and grasped with clamps. If any vessel cannot be drawn out or isolated, it should be secured by passing a sharply-curved needle carrying a catgut suture through the soft parts around the bleeding vessel (page 90, Fig. 78). The suture is then tied so as to include the soft parts and the vessel. Small vessels can be closed by torsion, as described in § 28. After all the vessels in sight have been ligated, the Esmarch elastic tourniquet is removed, while the amputation wound is elevated and pressure exerted upon it by aseptic sponges. Pressure lasting a couple of minutes is the best means of arresting the ensuing parenchymatous hæmorrhage, which is very apt to be considerable immediately after the removal of the Esmarch tourniquet, on account of the vasomotor paralysis that it causes.

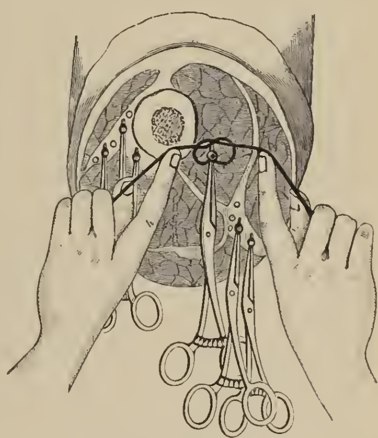


Fig. 106.—Ligation of the vessels in an amputation stump.

When the hæmorrhage has been very carefully arrested the large nerve trunks are drawn out of the wound and cut off with scissors, to prevent the possibility of any subsequent neuralgia or the formation of amputation neuromata. After this the wound is disinfected, together with the parts surrounding it, by irrigation with a 1-to-1,000–5,000 bichloride solution, or a three-per-cent. solution of carbolic acid, and its margins are united by sutures and drainage tubes inserted. If the asepsis has been perfect throughout, there is no necessity of antiseptic irrigation of the wound, as this only causes irritation and increases the subsequent discharge from the wound. It is sufficient to wash out the wound with a sterilised seven-tenths-per-cent. solution of common salt or simple warm boiled water. The drainage tubes are fastened to the skin by a suture, one tube being generally placed in the posterior flap, and, when necessary, others are placed in the angles of the wound at each side (§ 31). The wound is closed (§ 33) by inserting several interrupted tension sutures and then a continuous catgut suture. Great pains must be taken in inserting the sutures. They should be even, and hold the margins of the wound in perfect apposition. All drawing and tension must be avoided. Neuber recommends the use of several rows of sutures for closing an amputation wound. He sutures first the periosteum, then the muscles, and finally the skin, and thus avoids the formation of any pockets. According to my ideas, this form of suturing is unnecessary and even bad, and I have found that an aseptic dressing, applied so as to exert suitable pressure, is entirely sufficient to prevent the formation of pockets.

An *aseptic protective covering* which exerts moderate pressure is the most suitable form of dressing for amputations. I usually moisten the wound with a 1 to 1,000 solution of bichloride of mercury, and then cover it with several layers of well-dried bichloride or iodoform gauze, or with gauze sterilised by dry heat at a temperature of 100° C. Over this I place sterilised cotton or my own wool dressing. Moss or jute cushions or pads are also good (see Dressing Materials, § 45). The dressings are held in position by mull or gauze bandages; the stump is placed in a slightly elevated position, and left for the time being uncovered, so that any secondary hæmorrhage may be recognised at once.

Subperiosteal Amputations.—Ollier, particularly, has upheld subperiosteal amputations, reasoning from the results obtained from experiments made on animals. He makes a flap from the periosteum to promote primary union of the deeply lying parts, and to prevent inflammatory complications from occurring in the medullary cavity. But when this method is used on man the results are not so good as the experiments on animals would seem to indicate. At present Ollier has himself given up periosteal flaps, and even

considers them harmful in children, on account of the tendency to form osteophytes, and superfluous in adults since the introduction of Lister's method of antiseptic treatment of wounds. On the other hand, Ollier is a very warm advocate of subperiosteal disarticulation (see Disarticulations).

Amputation, with Scraping Out of the Diseased Medullary Cavity.—In diseases of the marrow of bone, such as suppurative osteomyelitis, König and Stoll have performed amputation accompanied by scraping out the marrow, and have obtained good results. In this way disarticulation at the adjoining joint above can be avoided.

§ 37. **The Method of performing Disarticulations.**—The technique is in the main the same as for amputations. The method by circular incisions at two levels, with turning back of a cutaneous cuff, can be used, or flaps may be cut of skin, or skin and muscular tissue combined.

In disarticulations, a long anterior overhanging flap and a small posterior one are much used, and are made as described above (Figs. 102, 104). In disarticulations at the ankle or medio-tarsal joint, or of the fingers or toes, the posterior flap can be made the larger. For disarticulation at the small joints of the fingers or toes, especially the metatarso- and metacarpo-phalangeal joints, the racket incision is very often used (Fig. 105).

After dividing the overlying soft parts in the form of skin flaps, or flaps of skin and muscular tissue combined, or after making the circular incision in two stages and turning back the cutaneous cuff, the ligaments of the joint are made tense and the joint opened. Whenever it is necessary, any prominent part entering into the formation of the joint can be cut away; and it is sometimes best to extirpate the synovial membrane completely, in order to obtain a wound surface to which the cutaneous flaps may unite more rapidly. The details for performing disarticulations are, in general, precisely similar to those for amputations.

For the method of performing disarticulation on particular joints, as well as the various amputations, the reader is referred to the textbook on special surgery.

Subperiosteal Disarticulation.—Ollier, especially, has recommended the regular use of subperiosteal disarticulation. Ollier's description is as follows: The same incision is made as for resection of the particular joint in question (see § 40), dividing at the same time both capsule and periosteum. By means of a raspatory the periosteum is elevated from the bone and pushed aside from the joint, together with such muscular insertions as are present; the head of the bone is then enucleated, and the soft parts cut transversely to the axis of the limb. Extensive new formation of bone has been observed after subperiosteal disarticulation, not only in animals, but also in man in early life. This is especially true of subperiosteal disarticulation

and amputation through the upper end of the metatarsus or metacarpus, and also after disarticulation at the tibio-tarsal joint with preservation of the periosteum of the os calcis. Ollier says that James Shuter of London has seen a new bone develop which was movable in the hip joint after subperiosteal disarticulation at this joint. The subperiosteal and subcapsular shelling out of the bone is probably of most use in case of disarticulations for gunshot injuries.

History.—During the middle ages and until the close of the sixteenth century amputations were done in the most horrible ways, on account of the inefficient methods then in vogue for arresting hæmorrhage, and usually ended fatally. The bleeding was checked by encircling the member to be operated upon with a strong rope, or the red-hot iron was used; boiling oil was poured over the wound, or the operation was performed with red-hot knives. Permanent constriction of the limb and caustics were also sometimes used. The technique was very greatly advanced by the introduction of the ligature of vessels by Ambrose Paré and his followers (1659–1692), and after this by the invention of the tourniquet by Morel (1674). The ligature of vessels for arresting hæmorrhage had been well understood by the surgeons of antiquity, and was in general use in the time of the Roman Empire. The ligature was afterwards entirely forgotten, as has been mentioned, and was later rediscovered by Paré.

In more recent times amputation was occasionally performed by the écraseur (Chassaignac), the galvano-cautery (Bruns), and the elastic ligature (Dittel). But now all these methods have become simply matters of history since the introduction of antiseptics.

§ 38. **The After-treatment of Amputations and Disarticulations.**—The after-treatment of amputations and disarticulations is very simple if no fever occurs and the wound runs a normal course in healing. The first dressing should not be disturbed till the time arrives for removing the drains—i. e., till the second, third, or fourth day, according to the size of the wound. Some of the stitches are also taken out at the same time. Then the second dressing is applied, and it is often the last. If fever occurs, or if the patient complains of pain, the dressing should be changed earlier.

For the details of treating the patient who has been operated upon, reference is made to § 22.

Bad Results.—Since the introduction of the present antiseptic method of operating and treating wounds the immediate bad results which have been observed to follow amputations and disarticulations are infrequent. It is generally expected that healing will take place without any reaction. The occurrence of wound infection—such as suppuration, pyæmia, septicæmia, erysipelas, and osteomyelitis, so frequently observed in the preantiseptic period—is now exceptional, and only takes place when an extremity is operated upon which is already infected, or when the rules of asepsis are not rigidly adhered to. For the treat-

ment of these diseases of wounds resulting from infection, as well as for the treatment of shock, delirium tremens, etc., reference is made to § 62 to § 75.

Amongst the other immediate bad results after amputation we may mention the occurrence of cramps or violent contractions of the muscles in the stump. These are liable to come on soon after the operation, and are best treated by subcutaneous injections of morphine and by fixation of the stump by means of light sand-bags, etc. (See also § 64, Delirium Tremens.)

Secondary hæmorrhage also occurs much less frequently than it formerly did, because we have learned to take great pains to arrest all bleeding during the operation. Secondary hæmorrhage starts either from an unsecured vessel which had retracted at the time that the bleeding from the stump was being stopped, or from a vessel which had been tied off but had opened again. In such cases of secondary hæmorrhage from an artery often nothing but the reopening of the wound and the securing of the bleeding vessel will suffice to check it. The best way of treating parenchymatous secondary hæmorrhage or oozing is to apply an aseptic dressing in such a manner as to exert proper pressure and to place the stump in an elevated position. At a later stage in the process of healing it is still possible for secondary hæmorrhage to occur from a perforation in the wall of the vessel resulting from suppuration when the wound does not heal by primary union. The treatment of this is also practically the same—i. e., the hæmorrhage should be stopped by applying a ligature to the point from which blood issues.

If the skin is very thin, or if the skin flaps lie upon a non-vascular surface like cartilage, as is the case in disarticulations, or if the dressings are applied so as to exert too much pressure, there is apt to be a more or less extensive death or gangrene of the flaps. In such cases one must either await the separation of the damaged portion of the flap, or, if the gangrene is too extensive, a higher amputation must be performed.

Sometimes necrosis occurs in the stump of the bone, especially if there has been suppuration. Under these circumstances one must wait until the sequestrum has become loosened, and then remove it. The bone stump does not necrose if the wound heals normally and without reaction.

Another bad result after amputation is the so-called conical stump. This may be the fault of the method of operating—i. e., the cutaneous flaps were made too short for sufficiently covering the bone stump, or it may be due to the death of part of the cutaneous flaps, or to retrac-

tion of the soft parts as a result of suppuration. This latter cause was relatively common in the preantiseptic period of surgery. At present conical amputation stumps are rare, and are usually the result of an unskilful performance of the operation. In a well-marked conical stump the end of the bone projects from the soft parts through the granulating surface of the wound, and either cicatrisation does not take place, or the slowly forming, adherent scar is so tense and sensitive that the use of the stump and the wearing of an artificial limb are impossible. Under such conditions there is nothing to be done but to perform a reamputation or a subperiosteal resection of the bone. The latter is best carried out by making a longitudinal incision through the soft parts and periosteum down to the stump of bone, care being taken to avoid large vessels and nerves ; the periosteum with the overlying soft parts are then separated by means of the raspatory and periosteal elevator from the bone, and a sufficiently long piece of bone is removed with the saw or hammer and chisel.

Since the era of aseptic surgery, the neuralgia of the amputation stump which used to occur after suppuration is seldom observed. The pain was usually caused by the stumps of the nerves becoming included in the contracting cicatrix which followed extensive suppuration. In other cases the pain is caused by a hyperplastic process occurring in the ends of the nerves and forming the so-called neuromata.

The amputation neuroma is usually a club-shaped thickening of the extremity of the nerve, and consists of connective tissue with more or less numerous bundles of newly formed nerve fibres. Very severe neuralgic paroxysms are occasioned by these neuromata and are aroused by the slightest pressure. The neuralgia which results from cicatricial contraction, and from neuromata, is best prevented by keeping the amputation wound aseptic, and by drawing out the ends of the large nerves with forceps after every amputation, and cutting off a considerable portion with scissors in order that the nerves may retract well between the muscles. Moreover, great care should be taken not to include nerves in the ligatures placed on the vessels. The treatment of neuralgia occurring in a stump consists in the excision of a long piece of the affected nerve trunk (neurectomy), and in the extirpation of any neuromata which may be present.

During the first few days or weeks many patients who have undergone an amputation complain of radiating pains of greater or less severity, which, however, gradually disappear in the great majority of cases. On account of irritation of the ends of the sensory nerve fibres which originally supplied the fingers or toes, these patients feel pain referred to those parts though they no longer possess them. The sensa-

tions referred to the portions of the extremities which no longer exist last a variable length of time—often a year—and patients are very likely to dream that they still have their lost limb.

Death following Amputation and Disartioulation.—A fatal result following amputation or disarticulation is either caused by one of the forms of wound infection, such as septicæmia, pyæmia, erysipelas, or tetanus, or by collapse, by anæmia from great loss of blood, by secondary hæmorrhage, delirium tremens, fat emboli, or other intercurrent diseases. In general, age does not play so important a part in the prognosis of amputations and disarticulations as it formerly did, because we have learned how to avoid loss of blood, and healing is more rapid with the aseptic method of operating. It often happens in old people that there is marked atheromatous degeneration of the arteries, and yet the wound will heal satisfactorily. Furthermore, syphilis, tuberculosis, and kidney disease have no such deleterious effect on healing as was formerly believed. In every case the prognosis after an amputation is favourable if there are no complications, and if there has been no transgression of the rules of antisepsis.

Mortality of Amputations.—The mortality of aseptic amputations varies with the nature of the case and the presence or absence of complications. According to Oberst, of 260 uncomplicated amputations 14 died, a mortality of 5·4 per cent.; but, on the other hand, there were 39 deaths in 91 cases where complications were present, a mortality of 42·8 per cent. Of 57 amputations in which sepsis was already present, 40 recovered, and, taking all cases without distinction, Oberst collected 351 amputations with 53 deaths, or a mortality of 15·1 per cent., and 84·9 per cent. recoveries. Wölfler has given the total mortality of amputations occurring in Billroth's clinic as 19·7 per cent. In uncomplicated cases the mortality was 5·7 per cent., and in those in which complications occurred—i. e., in amputations where sepsis and pyæmia were already present—the mortality was 43·7 per cent. Essen (in Wahl's clinic) gives the total death rate as 17·9 per cent., the mortality of uncomplicated cases being 5·93 per cent., and of those with complications 42·8 per cent. The mortality of the 255 amputations performed in Czerny's clinic was only 2·7 per cent. (Schrade). The decrease in the mortality is to be ascribed solely to the aseptic method of treating wounds, and the mortality of amputations and disarticulations would be still less if all the operations could be performed immediately after the injury.

§ 39. **Artificial Limbs.**—The substitution of artificial limbs for lost extremities has become more and more common in recent years. In the case of the lower extremity, the prothetic apparatus need only render standing and walking possible, and consequently it is conceivable that more satisfactory results can be obtained here than in the upper extremity, where the manifold movements of the hand and fingers can be only partially supplied; and not every one is in a position to pro-

vide himself with such costly apparatus as artificial arms and legs, with their complicated mechanism. As to the upper extremity, the movements of the fingers are usually imitated by spiral springs, or springs are placed in the apparatus in such a way as to make the latter movable when manipulated by the other hand or pressed against the thorax by the stump, etc. The simplest and cheapest prothetic apparatus for an amputated arm or forearm consists of a leather socket in which the stump is placed and retained by straps. At the other or lower end of the piece is fastened a hook, ring, or hand carved in wood and covered by a glove. It is remarkable how much some patients can sometimes accomplish with such a simple apparatus.

After amputation or disarticulation of the lower extremity we make use either of the peg leg or the artificial limb. The peg leg is the cheaper and by far the simpler apparatus, and with it walking is generally easier and more comfortable than with the artificial limb. Many who have long been tormented by the latter turn finally to the use of the peg. And it is worth taking into consideration that the peg leg can be repaired by any mechanic, while the artificial limb requires a skilled instrument-maker. Trendelenburg and others have shown that the peg leg can be improvised very cheaply by fastening a stick of wood to a socket made of pasteboard by means of a water-glass bandage. The artificial leg is usually made of a leather pocket in which the stump is placed; to this is joined the leg, which is made of wood, having hinges for the knee and ankle joints. The foot can be extended, when pressing against the ground, by means of a strong spiral spring. The movement of the knee joint is accomplished by some elastic material placed inside the leg and simulating the function of the muscles.

In a case of low amputation of the leg, A. Bier made an artificial foot from the end of the tibia with its overlying soft parts by dividing the bone again a little above the line of amputation and turning the piece so that it would unite with the tibia at right angles; the lower portion of the fibula was extirpated. If only a part of the foot is lost the defect can be concealed and walking rendered possible by padding an ordinary boot with cotton. These brief remarks will suffice for a general understanding of the principles of artificial limbs.

§ 40. **Operations on Joints.**—By *resection* of a joint is meant the partial or complete operative removal of the opposed bony surfaces forming the joint by means of the saw, sharp spoon, or chisel. A distinction is made between partial and complete resection, depending upon whether the ends of the bone are completely or only in part removed. If the joint is extensively diseased, we do not satisfy ourselves with removal of the bony portion, but also extirpate the synovial

membrane—i. e., we perform a complete extirpation of the joint. In all cases in which the periosteum is healthy we preserve it on account of its osteoplastic power, and call a resection of this kind subperiosteal. A distinction is made between early and late resection and between primary, intermediate, and secondary resection. By primary resection is meant one which is performed immediately after the traumatism has occurred and before the onset of inflammatory reaction. The intermediate resection is performed after inflammatory symptoms appear. A secondary resection is one performed after the subsidence of the inflammatory reaction, when the wound is granulating.

Resection of Bones in Continuity.—Furthermore, we resect bones in their *continuity* when we remove greater or less amounts of diseased portions of them by means of the chisel or saw (Resection of Bones). The removal of diseased bone by the sharp spoon—for example, in tuberculosis—is designated as a scraping out, while the simple division of bone in its continuity is called osteotomy.

Arthrectomy.—If the bony parts forming the joint are left intact, and only the diseased synovial membrane of the joint is removed, as in tuberculosis, the operation is an arthrectomy. The simple opening of the joint is called arthrotomy. We shall confine ourselves here to the general technique of joint resections, and shall take up the resections of particular joints in the Special Surgery.

Indications for Resection of a Joint.—The *indications* for resecting a joint, especially for performing total resection, have become much fewer in number since the introduction of antiseptic surgery. At the present time we are often able to save a joint—one, for instance, which has been laid open by a wound—where formerly it would have been sacrificed. We now go on the principle of performing a resection as conservatively as possible—i. e., we try to preserve as much of the articular surfaces of the bone as we can. The complete resection of joints in children, which used to be so frequently performed for tuberculosis, should be entirely given up. In these cases we should be satisfied with removing the diseased portion of the bone with the sharp spoon or the chisel, with the single exception of the hip joint; and in adults the use of total resection should be restricted as much as possible, and as much bone saved as possible. If only the capsule of the joint is diseased—as, for example, in tuberculosis—only this should be extirpated (arthrectomy), and the bony portion of the joint should be left intact. When arthrectomy is performed—for instance, at the knee in a case of synovial disease—a movable joint may be obtained (Angerer, Sendler, myself, and others). On the other hand, it cannot be denied that a very good functional result is possible after an extensive atypical resec-

tion, as in the case of the foot, and amputation be thus avoided. I agree with Kappeler, Mikulicz, Küster, and others in sanctioning extensive atypical resections, particularly of the foot.

In general, resection of a joint is indicated after severe injuries (traumatic resection) and for pathological changes in the joint (pathological resection). Among injuries of a joint calling for resection are (1) compound fractures involving the joint, with considerable splintering of the bones, especially gunshot fractures; also dislocations accompanied by rupture of the skin and overlying parts. Since the introduction of antisepsis it will often be found sufficient in these cases to drain the joint thoroughly after reducing the dislocation or removing whatever loose fragments are entirely detached. Resection of a joint is also called for (2) when there is very extensive suppuration or violent inflammation in the joint after an injury, and especially when there is (3) chronic disease of the joint, tuberculosis being the most common. Resections may also be performed for (4) loss of function in a joint caused by contractures or anchylosis, and in old dislocations in which there is a malposition of the bones which interferes with the functions of the joint, or in which the head of the bone presses on nerves and vessels, and finally (5) for new growths in the bones.

Osteoclasis, or subcutaneous fracture of bones by the osteoclast (Mollière), has of late years been used very largely in place of the so-called orthopædic resections for improving deformities of bone. But I agree with Ollier, that osteoclasis is not always as effective as its inventor claims; and, furthermore, it is not always possible to break the bones at precisely the desired point and without damaging the soft parts. Osteoclasis cannot usually be employed in cases of anchylosis.

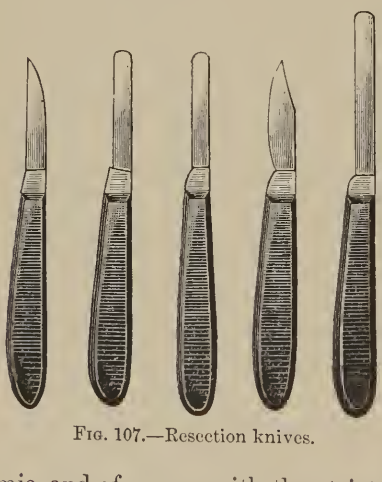


Fig. 107.—Resection knives.

General Rules for performing Resection.—The operation of resecting a joint is divided into three stages: (1) The incision through the soft parts; (2) opening the joint; (3) division and removal of the injured or diseased ends of the bones with or without extirpation of the synovial membrane. When possible, the operation should be performed with the aid of Esmarch's artificial ischæmia, and of course with the strictest aseptic precautions. The soft parts are divided with a short, strong knife (Fig. 107). Resection knives are

sometimes pointed, sometimes blunt, or fitted with a probe point. The incision through the soft parts is made preferably in the long axis of the limb, because this involves the least injury to muscles and tendons at their point of insertion, as well as to vessels and nerves. Only in the case of the knee—and, under certain conditions, the ankle—are transverse incisions allowable for affording a better view of the diseased joint. The joint is opened in the line of the cutaneous incision. It is very important for the future function of the joint to preserve the tendinous insertions of the muscles about the joint and to keep intact their connection, as well as that of the capsule with the periosteum. In all cases where the periosteum is healthy, as in primary traumatic resections, it should be preserved—i. e., a subperiosteal resection should be performed. If it is diseased, it must of course be removed, as well as the bone. If the periosteum is to be retained—that is, if we are going to do a subperiosteal resection—it is divided in the line of the cutaneous incision and raised by the raspatory (Fig. 63) and periosteal elevator (Fig. 64). At those places where the periosteum becomes continuous with the capsule, muscular insertions, and ligaments, it must be separated from the bone by perpendicular or horizontal strokes of the knife.

Vogt and König have introduced an excellent plan for retaining the connection of the muscular insertions to the bony protuberances to which they are attached. These protuberances are separated from the shaft of the bone by the hammer and chisel, or, in the case of children, by the knife, and at the conclusion of the operation they are again brought back into place and secured by means of silver wire or nails. When there is a tubercular panarthritis, or when diseased, it would of course be a mistake to preserve the periosteum. In such cases the joint must be entirely extirpated—i. e., all diseased soft parts and bone must be removed.

The periosteum having been removed, or left in place, as the case may be, the next step is the division of the bone (see § 26). The ends of the bone are forced out of the wound, while the soft parts are held aside by retractors, or the bony parts are divided *in situ* with the metacarpal, bow, or chain saw, or with the chisel. The bones of children can be cut with the knife. After division of the bone all projecting angles are levelled off.

If anchylosis is desired—for example, in the case of the knee—the ends of the bones are fastened together with catgut, silver wire, or four-cornered steel nails which have been carefully disinfected (see also § 34). Since partial resections give in general a better functional result than total ones, the former should be given, when possible, the preference in all joints in which we wish to obtain motion. The

strictest asepsis must be maintained in all stages of the operation. At its conclusion the hæmorrhage must be arrested with the utmost care, drainage of the joint must be provided for, and, after suturing the wound and applying an antiseptic dressing, the joint must be immobilised by a suitable splint. If the operation is performed with artificial ischæmia, it is best to remove the elastic cord and arrest the bleeding before suturing.

In case of extensive suppuration of a joint, or advanced tubercular disease, the wound should not be closed with sutures, but packed with iodoform gauze or sterilised compresses. When only a few interrupted sutures are inserted and the wound is left partially open, drainage may be dispensed with. If no reaction follows, a plaster dressing can be placed over the antiseptic dressing after a few days.

For the method of dressing individual joints after resection, reference is made to the text-book on special surgery.

Outcome of Resections of Joints.—The results of joint resection are either anchylosis, or an actively movable joint, or a so-called flail-like joint. In the lower extremity, at the knee and ankle, anchylosis is the most desirable result. In the hip and upper extremity a movable joint is preferable. For restoring the function of a joint after the wound has healed, the after-treatment is of great importance. It is possible to obtain very excellent results by the methodical use of active and passive motion, by electricity, massage, and baths. If anchylosis is desired, the joint should be immobilized in the position which is most suitable for subsequent use, by means of a plaster dressing or a splint left in place for a considerable length of time (see Methods of Dressing, and the special surgery). If a flail-like joint is obtained, it must be re-enforced by a suitable supporting apparatus, or another operation must be done to obtain anchylosis (see Arthrodesis, below).

The *causes of death* following resection are the infectious wound diseases, such as sepsis or pyæmia, due to imperfect asepsis, or to their presence at the time of the operation. Patients who have undergone this operation sometimes die from fat emboli, especially when there is advanced fatty degeneration of the bone marrow. P. Vogt has very properly advised that bones in which there is this fatty degeneration should not be joined together too closely.

History of Resections.—Resections were performed in the flourishing days of surgery at the time of the Roman Empire, but were forgotten entirely during the middle ages, and were not again systematically practiced till near the close of the eighteenth century. In England, White was the first to use the operation, performing a resection of the humerus. In France the operation was employed by Moreau; later by Sabatier, Percy, Dupuytren,

and Larry. Von Textor, B. von Jäger, and Ried introduced the operation amongst German surgeons. Langenbeck has done more than anybody to advance the technique of joint resection.

Arthrodesis.—By arthrodesis is understood the artificial anchylosis of a flail-like joint—in cases of paralysis, for example, in which it was first practiced by Albert, who operated with excellent results on both knee joints of a young girl suffering from paralysis of the lower extremities. The operation is very useful, especially for paralytic flail-like joints. At first arthrodesis was frequently performed by fastening the bones together with a wire suture after a typical resection of their joint surfaces. But it is a better plan to pare off only the articular cartilages, and then unite the bones with long, perfectly sterilised steel nails instead of the silver-wire suture. The synovial membrane should be allowed to remain intact. If healing takes place with some slight amount of suppuration, the synostosis of the joint ends of the bones is more solid than if the wound unites by primary union (Zinsmeister). H. Euringer has collected from literature sixty-eight cases of arthrodesis (in fifty patients), of which the majority were successful, and enabled the patients to dispense with the heavy, uncomfortable, and expensive splint apparatus.

CHAPTER X.

OPERATIONS FOR REMEDYING DEFECTS IN THE TISSUES.—PLASTIC OPERATIONS.—TRANSPLANTATION.

Plastic operations for loss of substance in the skin.—General methods of plastic surgery in case of loss of substance in the skin: movability of skin; liberating incisions; formation of flaps with pedicles; implantation of entirely separated portions of skin.—Skin-grafting by the methods of Reverdin and Thiersch.—Grafts of skin or mucous membrane taken from animals.—Hair-grafting.—Plastic operations for defects in other tissues (muscles, tendons, nerves, bones).

§ 41. **Plastic Operations for Cutaneous Defects.**—If the loss of substance in the tissues is so great that it cannot be remedied by simply suturing together the borders of the wound, we perform what has been called by the general name of a plastic operation, for remedying the defect or bringing about a more rapid cicatrisation.

We shall first take up the operative treatment of loss of substance in the skin. These defects are either fresh and the result of an injury or an operation, or they are old or congenital, or made up of a granulating wound surface. For treating such defects in the skin, or for hastening cicatrisation, there are in general two principal methods:

1. The closure of the defect by traction upon the skin in the neighbourhood, and by the formation of a cutaneous flap, which is freed from the underlying parts in such a way that it still possesses a bridge of skin at some portion of its circumference, called a pedicle, connecting it with the neighbouring skin.

2. The defect is also remedied by the transplantation or implantation of an entirely detached portion of skin. This latter method has been perfected by Thiersch, and is now very frequently used for placing an epidermic covering over a fresh or granulating defect in the skin or mucous membrane (see page 141). The first method, in which the defect is remedied by traction on the surrounding skin and by the formation of a movable flap with a pedicle, is what is ordinarily meant by a plastic operation, but it has been largely supplanted by Thiersch's method of skin transplantation or skin grafting.

Defects not only in the skin, but also in muscles, tendons, nerves,

and bone, can be remedied by plastic operations—i. e., by the formation of flaps with pedicles or by the transplantation of portions of tissue entirely separated from their original surroundings.

Modern aseptic surgery has made great advances in plastic operations and in the grafting of different tissues on others. Portions of tissue, such as bone, nerve, or skin, which have been completely severed from the body, will only unite in their new position when no suppuration occurs, and it is consequently of the greatest importance that there should be primary union.

The cutaneous defects in which plastic operations are called for are caused by injuries and by diseases of every description (wounds from freezing, burning, inflammation causing necrosis, operations for tumours, malformations like harelip, ectopia vesicæ, etc.). Plastic operations are also indicated in cicatrices causing deformity or loss of function in a part. German surgeons especially—Gräfe, Dieffenbach, Langenbeck, König, Thiersch, and others—have devoted themselves to advancing the methods for performing plastic operations. The ancient surgeons, particularly in India, were skilled in this branch, having plenty of opportunity for performing rhinoplasty and otoplasty, on account of the frequency of the form of punishment which consisted in cutting off the nose or ears.

The Healing in Place again of a Completely Severed Portion of Tissue.—If small portions of the body, like the tips of the fingers or the nose, are completely cut off, they will sometimes reunite in their proper position by primary union if they are carefully sutured in place with every antiseptic precaution, provided the piece of tissue is not too large and not too much crushed, and the sutures are applied immediately after the receipt of the injury. We shall return to the subject of the reuniting of small, completely severed portions of tissue in the chapters on Injuries and the Repair of Wounds.

As to the time when plastic operations should be performed, we have stated that they may be done at once on a fresh wound, immediately after the termination of an operation like the removal of a cancer from the lip, or as one of the steps in operating on harelip, etc.; or, on the other hand, on a granulating surface. If the loss of substance in the skin is due to a crushing wound, we should wait until it can be definitely determined how much of the crushed tissue will survive. When a granulating wound is to be covered with a cutaneous flap having a pedicle, it is best to change the granulating surface into a fresh wound by scraping or cutting off the granulation tissue, and upon this surface to engraft the skin flap. On the other hand, granulating skin flaps can be safely transplanted, for example, on to a defect in the anterior wall

of the bladder (ectopia vesicæ). It has already been mentioned that in other cases we are able to perform plastic operations after actual cicatrization of the wound has taken place, or after extirpation of a scar which is unsightly or interferes with the function of a part.

General Principles of Plastic Surgery.—The following is a brief statement of the general principles governing plastic surgery, the details of which for special plastic operations—such as rhinoplasty, cheiloplasty, the operations for ectopia vesicæ, etc.—will be considered in the text-book on special surgery.

It is of the greatest importance for the success of any plastic operation, or for the union of a skin flap in its new bed, that the operation should be conducted with the strictest attention to asepsis. The borders of the wound should be as smooth and sharply outlined as possible, the flaps should be cut of adequate size, not too small or too thin, and the subcutaneous fatty tissue should be preserved in its connection with the flap. The sutures should be of catgut or fine aseptic silk, and should be so applied that the borders of the wound are held in exact apposition.

Coaptation of the Borders of the Wound and Freeing of the Skin from Underlying Parts.—The simplest way of closing a defect in the skin consists in drawing together the borders of the wound and uniting them with sutures. To render the edges of skin more movable, they can be dissected free, together with the attached subcutaneous fat, from the underlying parts. Thus cutaneous defects of the most diverse shapes, if not too large, may be easily closed, as illustrated in Fig. 108. Julius Wolff has recently elaborated this method of closing defects by drawing over them the adjoining skin, which has first been freed from the subjacent parts, and then suturing the edges of the skin. He has in this way closed large areas where loss of substance has occurred in skin and in bone, and has also applied it to widely opened joints. The skin is loosened for some distance around the wound, partly with the hand and partly with a probe-pointed knife or scissors, and then brought over the wound and sutured (Berlin. klin. Wochenschr., 1890, No. 6).

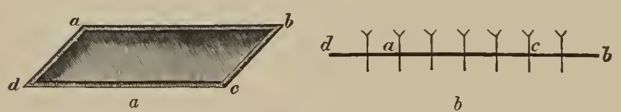


FIG. 108.—Union of the borders of an area where there has been a loss of substance in the skin; the edges of the skin are freed from the underlying parts and united by sutures: *a*, before inserting the sutures; *b*, after inserting the sutures.

In other cases it is best to make use of lateral liberating incisions; i. e., before or after inserting the sutures in the approximated margins of the wound, an incision is made parallel to and at one side of the su-

ture line, in order to lessen the tension on the suture line (Fig. 109, *a*). As illustrated in Fig. 109, *b*, the liberating incisions cause slightly gaping wounds after the defect has been closed, but these usually heal rapidly by aseptic granulation.

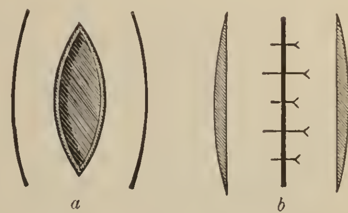


Fig. 109.—Lateral liberating incisions: *a*, before inserting the sutures; *b*, after inserting the sutures.

In a third category of cases the skin is drawn over a defect after making one or more incisions prolonged from the limit of the original defect in any required direction, and by this means forming a kind of flap. This is only a modification of the method of closing a defect by sliding the skin over it, and does not belong to the important method of plastic surgery about to be described—namely, the formation of a flap with a pedicle. In Figs. 110, 111, and 112 are seen examples of the application of this method. In Fig. 110, the original incision has been prolonged in the line *c d*, and the portion of skin *a c d* is thus rendered capable of being moved, *c* being drawn over to *b*, and the two borders of the defect are united with sutures, giving the result illustrated in Fig. 110, *b*. In the same manner, under other circumstances, a second incision can be prolonged from the original defect at *b*. When the three-cornered defect is closed by sutures there results some slight puckering of the skin at the sides. Burow remedies this by excising small three-cornered portions of skin in this region. This plan of excising a triangular-shaped portion of tissue, which Burow intro-

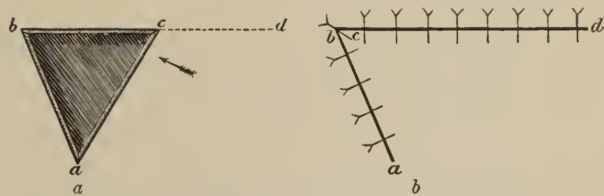


Fig. 110.—Incision prolonged from one corner of a triangular wound: *a*, before, and *b*, after inserting the sutures.

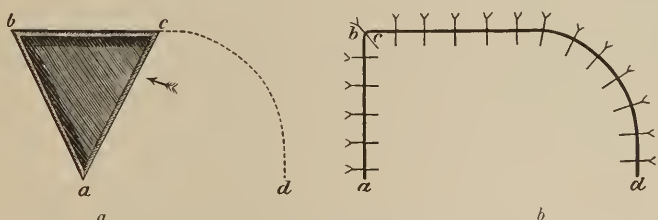


Fig. 111.—Curved incision from one corner of a triangular wound: *a*, before; *b*, after inserting the sutures.

duced, is at present but little used. In Fig. 111 the liberating incision *c d* is prolonged from the edge of the defect in a curved direction, and

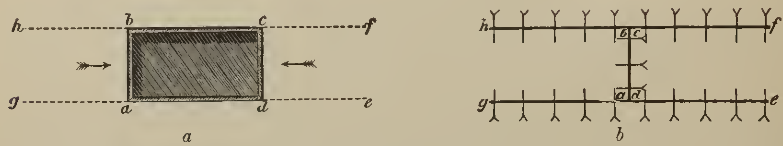


Fig. 112.—Prolonged incisions for uniting a four-cornered wound: *a*, before; *b*, after inserting the sutures.

here also a second curved incision from *b* can be employed with advantage for closing the defect by sliding over it a portion of the adjoining skin. In Fig. 112 four lateral incisions are made for closing a quadrilateral defect. This principle of making lateral incisions or prolonging the original incisions, followed by drawing the skin over the defect, is capable of almost endless variations.

Formation of Flaps with Pedicles.—The most important method used in plastic surgery consists in fashioning flaps which have a pedicle —i. e., cutaneous flaps which remain connected with their original locality in the skin by means of a bridge or pedicle through which they are nourished, but throughout all the rest of their extent they are completely separated from their original bed. After this has been done

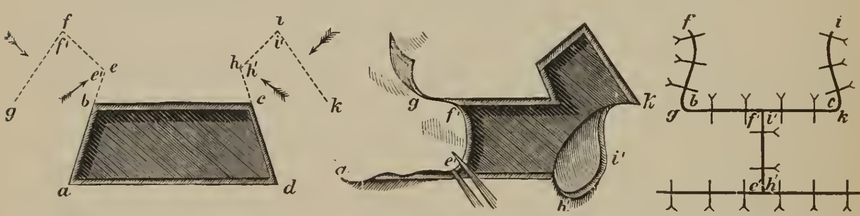


Fig. 113.—Formation of two lateral flaps of skin: *a*, before; *b*, after inserting the sutures.

the flap is laid in the defect, as illustrated in Fig. 113, *b*. In Fig. 113 two lateral flaps are fashioned (Fig. 113, *a*) and placed in the defect (Fig. 113), so that Fig. 113, *c*, results when the edges of the wound are united by sutures. In Fig. 114, *a c*, is illustrated the method of performing a complete rhinoplasty. For details and other methods of performing rhinoplasty reference is made to the Special Surgery.

When flaps with pedicles are used care must be taken that the blood supply is good and that primary union is obtained. The pedicle must be so situated that as many vessels as possible enter the flap; and the pedicle must not be too narrow or too thin. The flap, particularly the portion constituting the pedicle, is freed with every precaution for

preventing its becoming too thin. Moreover, it is important that the part representing the pedicle should not be subject to too much ten-

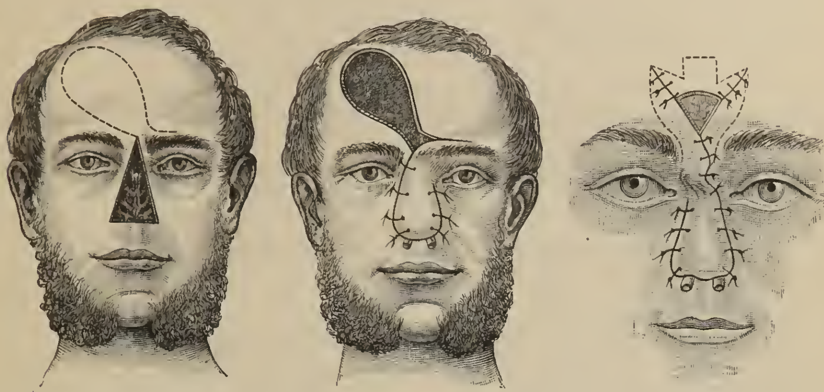


Fig. 114.—Rhino-plasty: *a*, freshening of the borders of the defect in the skin, and formation of the pear-shaped flap on the forehead; *b*, after placing the flap over the defect in the skin; *c*, Langenbeck's method for performing rhino-plasty.

sion when the flap is implanted on the defect, for otherwise the nutrition might be materially impaired.

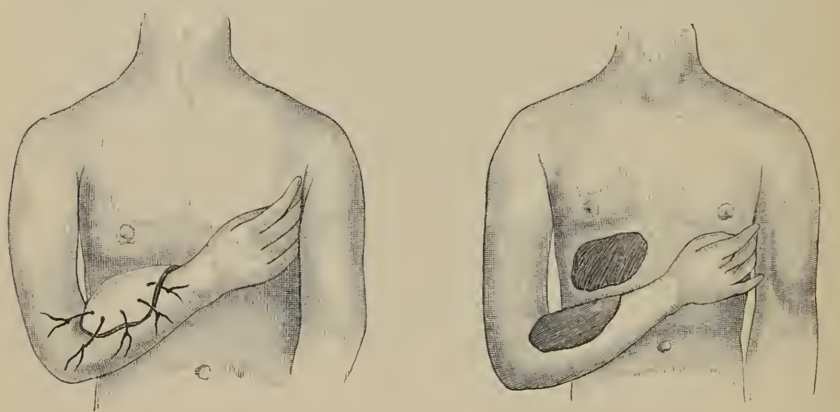
Plastic surgery performed with flaps having a pedicle was the form in which it was especially used by Indian surgeons, and they probably originated it.

Flaps have also been fashioned from portions of the body widely separated from the defect, as we shall see when we take up rhinoplasty. Tagliacozzi (Taliacotius, 1597), a physician of Bologna living in the sixteenth century, was the first to use a flap fashioned from the skin in the biceps region of the arm, and after placing the arm over the nasal defect and allowing the flap to heal into the latter, he cut the flap loose by dividing its pedicle (Fig. 115). This Italian method, as it is called, is only applicable to those exceptional cases in which good material for making the flap cannot be obtained in the neighbourhood of the defect. The Italian method is usually performed in three stages: (1) The formation of a flap which remains attached by two pedicles; the flap is separated from the underlying parts after making two lateral incisions, and its reunion prevented by iodoform gauze or oiled silk placed under

Fig. 115.—Italian method of performing rhino-plasty (Tagliacozzi and Graefe).

the flap. (2) After granulation has become well established one pedicle is divided, and the flap is sutured into the defect (Fig. 115). (3) After the flap has healed into its new bed, or after eight, ten, or fourteen days, the other bridge of skin or pedicle is divided. Graefe has performed the Italian method in one sitting by bringing the flap directly in contact with the defect (the German method). But the nutrition of the fresh flap is often poor, and it is likewise very apt to shrink.

In recent times this method of remedying defects by transplantation of pedunculated flaps from distant portions of the body has been revived, and fresh flaps of this kind, taken, for example, from the thorax, have been transplanted to fresh and granulating defects in the



a *b*

FIG. 116,—The manner of remedying losses of substance at the bend of the elbow, and on the forearm by pedunculated flaps of skin from the thorax: *a*, pedunculated flap of skin which still remains attached to the thorax, and which has been sutured into the defect; *b*, after it has healed in place.

arm and forearm, and have thus prevented contractures of the elbow joint after burns, avulsion of the skin, etc. (Maas, Langenbeck's Archiv, Bd. xxxi; Wagner, ibid., Bd. xxxvi, 1887, S. 381; and V. Hacker, Bd. xxxvii).

Granulating Skin Flaps.—Not only fresh but also granulating skin flaps are used, as we have seen, especially for closing congenital defects in the bladder (ectopia vesicæ). (See Special Surgery.) For closing a defect in the wall of a cavity, as in ectopia vesicæ, and defects in the cavity of the mouth following, for example, the removal of a cancer, Plessing has recommended the use of flaps covered with epidermis. After fashioning a skin flap with a pedicle, its wound surface is provided with epidermis by Thiersch skin grafts (see p. 141), and then the graft is allowed to heal into the defect.

Skin Flaps with a Pedicle of Subcutaneous Tissue—Gersuny's Meth-

od.—Gersuny was the first to show that a skin flap which possessed only a pedicle of subcutaneous tissue would receive sufficient nourishment to enable it to be used for plastic purposes, particularly in remedying defects of mucous membrane. The flap is simply turned into the defect like a door on its hinges, or it is drawn into a more deeply lying region through a suitably placed slit or wide button-hole.

Transplantation of entirely severed Pieces of Skin.—Moreover, pieces of skin which have been *entirely separated from their original bed* can be implanted in defects. Wecker and others have, in the case of defects of the lower eyelid (ectropion), successfully implanted a single flap of skin which did not even possess a pedicle. This method has been long practiced by the Indian surgeons, but, in spite of even the present aseptic way of doing this, it is still a matter of uncertainty whether a portion of skin which includes the entire thickness of the cutis will heal into its new position. To Réverdin and to Thiersch especially belong the credit of having given a practical surgical importance to the method of transplanting portions of skin entirely severed from their original bed.

§ 42. **Skin-grafting according to Réverdin and Thiersch.**—In 1870 Réverdin used his method of epidermic or, more correctly, skin-epidermic grafting for causing a granulating wound to skin over more rapidly than it otherwise could, as a granulating wound, in which the corium is entirely absent, can only become covered with skin by a very gradual ingrowth of the latter from the edges. It is only possible for skin to start to grow outwards from the middle of a granulating surface when there still remains in this area remnants of the rete Malpighii or of the sebaceous glands. By Réverdin's skin-grafting not only is the length of time required for a wound to skin over shortened, but the subsequent cicatricial contraction is considerably diminished. The way in which Réverdin originally practiced this was very imperfect, and Thiersch was the first to develop a useful and satisfactory method of skin-grafting or skin-transplantation. The skin is applied to a fresh defect after the bleeding has been thoroughly arrested ; but if the defect consists of an old granulating surface the granulation tissue must be first removed with the knife or sharp spoon. Nevertheless, skin can also be transplanted on to a granulating surface, especially in the case of a granulating area of bone. Moreover, skin for transplanting purposes can be taken from a fresh cadaver before the onset of rigor mortis, and from a part which has just been amputated, etc.

Thiersch's Method of Skin-grafting.—The instruments to be used are sterilised by boiling them for about five minutes in a one-per-cent. soda solution and are then placed in a sterilised six-tenths-per-cent. solution

of common salt. Antiseptic solutions like bichloride of mercury and carbolic acid should not be used, as they endanger the vitality of the cells in the pieces of skin to be transplanted. The latter are taken preferably from the arm or the lower extremity, etc. The area of skin in question is thoroughly washed with sterilised soap and warm water and shaved. As large a razor as possible, or a microtome, is covered with sterilised oil, and while the skin to be cut is put on the stretch, *as thin flaps as possible* are shaved off from it. To secure rapid healing, the pieces of skin should be laid upon a wound from which the blood has been removed as completely as possible (Garré). The very thinnest piece of skin thus obtained contains, besides the entire thickness of the papillary layer, a part of the underlying stroma. In this way pieces of skin ten to twelve centimetres long and two centimetres broad can be made to heal into their new position. The larger grafts are carried upon an especially broad spatula and then spread out over the defect with a probe. Great care should be taken that the edges of the piece of skin do not roll up, and the separate pieces should be placed next one another with their edges just touching. This method is particularly valuable for fresh cutaneous defects caused by operations or injuries, for burns in the stage of granulation, for ulcers of the leg, for broad and deep granulating areas following operations for necrosis, etc. After removing a large, soft fibroma, I successfully covered with epidermis almost the entire hairy portion of the scalp in one sitting by Thiersch's method of skin-grafting; I also made a large permanent opening into the left pleural cavity for empyema and tuberculosis, and changed it into a gutter by use of the same method (see Special Surgery, § 126, p. 400, Fig. 296). In short, the method is an excellent one. Thiersch has also transplanted the skin of a negro upon a white man and the skin of a white man upon a negro. The negro's skin took root on the white man with exceptional rapidity, but the attempt failed in the majority of cases in which skin was transplanted from the white man on to the negro, no matter whether a granulating or a fresh wound surface was used. It is interesting to note that the portions of white skin implanted on the negro gradually turned black, and *vice versa.* The histological investigations of Karg showed that the pigment does not originate in the cells of the rete Malpighii, but is brought to them by the wandering cells which come from the deeper-lying portions of tissue laden with pigment and find lodgment amongst the cells of the rete. Consequently the white skin implanted on the negro becomes gradually black, and the negro's skin implanted on the white man becomes white from ceasing to receive deposits of pigment. The pigment particles are probably identical with the cell granules

discovered by Altmann and by him called bioblasts, and are probably formed from them by the help of the blood in some unknown way. According to Jarisch, the pigment of the negro's skin lies almost entirely in the deeper cells of the rete Malpighii and is entirely, or almost entirely, absent from the more superficial cells.

Dressings after Skin-grafting.—The *dressing* for an area of *transplanted skin* should be one which does not adhere to its surface, as the pieces of skin are easily torn off when the dressing is changed. It is best to cover the grafts with strips of sterilised tin or gold foil, or rubber tissue dipped in sterilised oil, and over these to place a dressing of sterilised compresses and cotton, which is bound on with a muslin and then a gauze bandage, exerting a slight amount of pressure. Antiseptics should be left out of the dressings altogether. The strips of tin foil, etc., are disinfected by a bichloride solution (1 to 1,000) and then placed in sterilised olive oil before they are applied to the wound.

Excellent results can be obtained in this way, and very large grafts will promptly become attached, provided only olive oil and a six-tenths-per-cent. salt solution are used, and the irritation of carbolic or bichloride solutions is avoided. I have also entirely given up covering the transplanted pieces of skin with iodoform. The first dressing should be left in place for two, three, or four days, and then removed with great care. If the grafts have "taken," the area they cover presents a mosaic appearance due to the separate pieces of skin used for the grafts. Later on the borders of the separate pieces of skin become less and less marked, and occasionally become quite indistinguishable. Until the grafts have become completely attached it is best to use the dressing of sterilised olive oil, with strips of tin foil or oiled silk. The epidermis generally comes off, and is liable to give the erroneous impression that the grafting has failed. Success is easily prevented by suppuration or bleeding. E. Fischer has made the interesting observation that those skin grafts become attached the easiest which are taken from and transplanted upon parts which have previously been rendered anæmic by the use of Esmarch's rubber bandage.

Wölfler's Transplantation of Mucous Membrane.—Wölfler (see Langenbeck's Archiv, Bd. xxxvii) has successfully transplanted mucous membranes taken from man and animals upon defects in various mucous membranes. His method is to be greeted as a new and valuable advance in the treatment of defects in mucous membrane, such as strictures and defects in the urethra, conjunctiva, cheek, etc. Gersuny, Witzel, and others have remedied defects in mucous membranes by turning in flaps of skin possessing a pedicle of subcutaneous tissue only (see page 140).

Implantation of Hair.—Schwenninger and Nussbaum have attempted to implant hair by strewing it over a granulating area where there has been a loss of skin. If the root sheath still remained attached to the hair, it became adherent and formed a centre from which cicatrisation proceeded, but the hair itself fell out after a few days. Hairs without their root sheath did not become attached at all.

Transplantation of Skin and Mucous Membrane from Animals (*Rabbits, Frogs*).—The skin and mucous membranes of animals have also been successfully transplanted upon man. The conjunctiva of a rabbit has been successfully grafted in a defect of the human eyelid. Baratoux and Dubousquet-Laborderie have succeeded in implanting the skins of frogs upon granulating wounds in man. The pigment disappeared after ten days, and the graft took on more and more the appearance of human skin. (For the minute anatomical changes concerned in the attachment of skin grafts, see § 61, The Healing of Wounds.)

§ 43. **Plastic Operations on other Tissues** (*Tendons, Nerves, Muscles, Bones*).—Plastic operations and graftings are performed not only upon the external cutaneous surface of the body, but also upon other tissues, such as tendons, muscles, nerves, and bones. We shall refer to this in detail later on. At present the following brief account will suffice: Defects or loss of substance in a tendon can be remedied by cutting flaps with pedicles from one or both divided ends of the tendon and bending them back and uniting them by means of sutures of catgut. In the same way I was able to repair a defect in the ulnar and median nerves by cutting flaps from the divided ends of the nerves to which the flaps remain attached by a pedicle. These flaps were turned down into the defects and united by catgut sutures. The result was completely successful. (See § 88, Injuries of Nerves and the Regeneration of Nerves.) Nussbaum likewise repaired a defect in the ulna by pieces of bone covered with periosteum, the graft, which had a pedicle, being taken from the end of the bone. Entirely detached portions of tissue have also been made to heal into defects. Philippeaux, Vulpian, Gluck, and others have thus ingrafted portions of a nerve taken from a rabbit into defects caused by loss of substance in a human nerve (see § 88). In the same way attempts have been made to remedy defects in muscles and bones by ingrafting corresponding kinds of tissue taken from animals. Loss of substance in bone—for example, in the skull or after total necrosis of one of the long bones—can be remedied by implanting small pieces of cartilage or bone taken from young animals or from an infant (Macewen, Ollier, etc.). The bone fragments should be small, about ten millimetres long and four to five millimetres thick, and, to obtain the best results,

should be taken from infants or young animals, and preferably from near the joints, where ossification is most active—i. e., from the neighbourhood of the junction of the epiphysis with the diaphysis in long bones. It goes without saying that the strictest asepsis and immobilisation of the extremity afterwards are indispensable (see § 101). Macewen and Poncet have remedied defects in bone resulting from total necrosis—for instance, of the humerus and the tibia—by transplantation repeated many times. In cases of pseudarthrosis, Ollier and others have successfully implanted large fragments of bone taken from infants or young animals. Gluck has recommended the filling of cavities and defects with foreign bodies of the most varied description, which are left permanently in place. He inserts, for example, ivory cylinders and ivory pegs in cases where there is a loss of substance involving the entire thickness of the bone, and he also makes use of pieces of ivory to form hinge or ball-and-socket joints. The experience of others in Gluck's osteoplastic and arthroplastic methods has not been published, and his own results are open to doubt. Senn, Le Dentu, and others have filled in defects in bone by means of pieces of decalcified bone. Zahn, Fischer, etc., have performed very interesting transplantation experiments with materials of the most diverse sorts, which cannot be discussed more fully at present, as they will be brought up again in connection with injuries of the bones and soft parts (see § 88 and § 101). It need only be said that living bone having as large a pedicle as possible for supplying its nutrition is the best for osteoplastic operations (the so-called homœplasty or autoplasty). If a piece of dead bone (ivory) is ingrafted in the wound it remains a dead body, and only fills the space it occupies for a certain length of time (heteroplasty).

SECOND SECTION.

THE METHODS OF APPLYING SURGICAL DRESSINGS.

CHAPTER I.

THE ANTISEPTIC AND ASEPTIC PROTECTIVE DRESSINGS FOR WOUNDS.

General principles governing the antiseptic and aseptic dressing of wounds.—History.—The typical Lister dressing; its simplification.—Antisepsis and asepsis.—The most commonly used antiseptic or aseptic dressing materials (gauze, cotton, jute, lint, wood fibre, moss, etc.).—The different antiseptics; their uses and dangers (poisoning from carbolic acid, bichloride of mercury, iodoform, etc.).—Which antiseptics are of value?—Which antiseptic and aseptic methods of dressing are the best?—Antiseptic and aseptic change of dressings.

§ 44. **General Principles governing Antiseptic or Aseptic Dressings.**—After learning, in the previous section, the main principles governing the modern aseptic method of performing operations, we come to the question of what dressings should be used for covering the wound, and the discussion of the methods of applying surgical dressings. It is a part of surgical technique which requires indefatigable diligence and care. A correct application of the dressings, and a carefully conducted after-treatment of those who have been operated upon or wounded, are matters of the greatest importance.

As we are aware that all infection of the wound is caused by micro-organisms, by the omnipresent bacteria, it follows that we should conduct the after-treatment of the wound in such a way as to preserve it from the damaging effects produced by micro-organisms, and with the same care that is used in performing an aseptic operation.

The surest and simplest way of preventing subsequent infection in a clean, aseptic wound—such as one resulting from an operation—is to cover it with a germ-free dressing which has been sterilised by hot steam (see pages 13, 14). In private practice, dressings are still much used which have been impregnated with antiseptics like carbolic acid and bichloride of mercury. That method of treating a wound is the best which offers the greatest security against subsequent infection and

most readily carries off and absorbs the discharge from the wound. We operate, without exception, according to the rules of asepsis, and consequently the same preventive measures should be carried out in the after-treatment of the wound until it has become entirely healed. Infected wounds are to be cleaned as perfectly as possible from any dirt or foreign bodies which may be present, and are best disinfected by a 1 to 1,000 solution of bichloride of mercury.

Historical Remarks on the Listerian Method of treating Wounds.—The antiseptic as well as the aseptic occlusive dressing for wounds has advanced very gradually to its present state of perfection. Lister began the use of his antiseptic occlusive dressing at the Glasgow hospital in 1865, and published his first communication on the subject in 1867. Thiersch was the first German surgeon to bring into notice Lister's antiseptic method of treating wounds, describing it in his work on the repair of wounds.* Then followed the contributions of Schultz and Von Lesser, who had in Edinburgh itself made themselves familiar with Lister's methods and praised them very highly. Even before Lister's discovery, antiseptics, especially carbolic acid, had been used for dressings, but to Lister belongs the immortal honour of having conceived and intelligently carried out the antiseptic method of operating and of applying dressings by the use of which it is possible to keep fresh wounds from infection. In 1872–'73 the first trials were made in Germany with the Lister dressing. In the German Surgical Congress of 1874 Volkmann reported his experiences with the Lister dressing, and in 1875 he published his "Beiträge zur Chirurgie," in which were described the remarkable and hitherto unheard-of successes obtained by the use of Lister's method of operating and applying dressings. In 1874–'75 the Listerian method came into general use in Germany, and then started on its triumphant progress over the entire civilised world. Never was surgery so radically changed for the better as after the introduction of Lister's method for the treatment of wounds. In the very hospitals where the infectious wound diseases had raged the worst during the preantiseptic period, the severest operation wounds and injuries now healed up without suppuration and without secondary disease. After such remarkable success, the opponents of the method who arose here and there were forced to give up the contest.

The Original Typical Lister Dressing.—The typical Lister dressing used at first was applied in the following manner: The disinfectant was carbolic acid, used in a two-and-a-half- to three-per-cent. solution for non-infected, and in a four- to five-per-cent. solution for infected wounds. Lister covered the wound, or, rather, the suture line, with carbolic acid and paraffine spread on oiled silk, the whole being called a "protective" for keeping the irritating substances in the dressings away from the wound. The protective was made of green silk cloth, painted over with shellac, and covered on one side with a mixture of one part dextrin, two parts pulverised starch, and fifteen parts of a five-per-cent. carbolic acid solution. Before using, the protective was disinfected by a three-per-cent. carbolic solution. The green colour of the pro-

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* Pitha-Billroth's Handbuch der Chir., Bd. i, p. 559.

tective was changed to black by decomposition of the wound-secretion, which was a matter of practical importance for determining whether the wound was perfectly aseptic or not. Besides the silk protective, a cotton protective was also in use. Over the protectives Lister placed eight or more layers of dry gauze impregnated with carbolic acid, and between the two outermost layers he inserted a water-tight material made of cotton and gutta-percha (mackintosh). The layers of carbolised gauze extended some distance beyond the limits of the wound, particularly when considerable discharge was expected. Lister used carbolised gauze bandages instead of the ordinary strong muslin bandages. He impregnated them with carbolic acid in the same way as the gauze compresses used in the dressing. The typical Lister dressing was always put on and changed in the early days under the carbolic spray (see page 12).

Improvements in the Original Lister Dressing.—Very soon after its introduction, Lister's carbolised gauze dressing was materially simplified and improved, particularly by German surgeons. The carbolic spray used during the change of the dressings was done away with, also the protective and the mackintosh. The wound is now covered only with aseptic dressings, and stress is laid upon the importance of having the secretion from the wound dry quickly in the dressing. The instruments are sterilised by boiling them for five minutes in a one-per-cent. soda solution, and bichloride of mercury 1 to 1,000–5,000 is used as the antiseptic for the wound. Sterilised water, or a sterilised six-tenths-per cent. solution of common salt, is frequently used for operations on such parts of the body as the peritoneal cavity, etc. (see § 6).

§ 45. **The Most Common Antiseptic and Aseptic Dressings for Wounds.**—The modern surgeon uses particularly:

1. *Antiseptic solutions* for cleansing the wound and for disinfecting the materials used in the dressings. The most suitable are three- to five-per-cent. solutions of carbolic acid, and aqueous solutions of bichloride of mercury (1 to 1,000–5,000). He also uses antiseptic powders, such as iodoform, boric acid, salicylic acid, and naphthaline, for dusting over wounds, especially if they have the form of a cavity or are not closed by sutures, or are already suppurating or granulating.

2. *Absorbent materials*, such as unstarched gauze, mull, jute, prepared moss, wood wool, my own specially prepared wool, and cotton from which all fatty matter has been extracted. These are sterilised by subjecting them to steam heat at a temperature of 100° C. (212° F.) in a sterilising apparatus.

The dressing materials impregnated with antiseptics, like carbolised and bichloride gauze, were formerly in very general use; but it is simpler and better to sterilise them all by heating them as just described, at a temperature of 100° C. (212° F.), in a sterilising apparatus. Moreover, it has been proved that dressing materials impregnated with antiseptics and kept in a dry condition do not remain sterile, but after a time all sorts of bacteria have been cultivated from them (Schlange,

Ehlers, and others). Bergmann, Schlange, and Kocher were the first to oppose the use of these kinds of dressings; and in the surgical clinic of the Berlin University and in Copenhagen (Bloch), materials for dressings were first used which had been sterilised simply by passing through them steam at a temperature of 100° C. (212° F.).

The modern surgeon no longer uses for dressing wounds the material called charpie, which was formerly much in vogue, and consisted of bundles of thread made by pulling to pieces bits of linen cloth. This charpie has caused much harm; it was full of dirt and wound-poisons, and, consequently, has killed many a patient by exciting suppuration and infectious wound diseases (erysipelas, pyæmia, septicæmia).

The dressing materials are fastened in place by mull bandages which have been soaked in a three-per-cent. carbolic or 1 to 1,000 bichloride solution, and gauze bandages are applied over these. The bandages subsequently dry and cause the whole dressing to form a firm, well-fitting support. When it is necessary to immobilise an extremity, the dressing may be strengthened by adding splints of wood, metal, wire, or thin pliable wooden hoops.

Of the numerous materials used for making antiseptic dressings, the following are in most common use:

Mull or Gauze.—The most extensively employed material is soft, unfinished gauze or mull. Mull is a most excellent substance for dressings, being soft and a good absorbent, but is somewhat expensive. It is impregnated with every kind of antiseptic, particularly bichloride of mercury, carbolic acid, and iodoform, but it is best sterilised by subjecting it to steam heat at 100° C. (212° F.), as we have described. For the method of preparing this or that particular kind of antiseptic mull—e. g., carbolised, or bichloride, or iodoform gauze, etc.—reference is made to the description of the various antiseptics which is given further on.

Other and cheaper materials are recommended as substitutes for the more expensive mull—these are jute, moss, prepared moss, wood wool, etc.

Cotton.—Cotton is not suitable for placing directly upon the wound, as it does not sufficiently absorb the secretion from the wound, and allows it to collect underneath and decompose. But after covering the wound with a good thick layer of some absorbent material, like mull or the author's prepared wool, it is then a good plan to use dry cotton, which has been freed from fat, as the outermost covering of the dressing.

Lint.—Lint has been manufactured, especially in England, since about the beginning of the present century. In combination with antiseptic substances, especially boric acid (making boric lint), it is very much used as an antiseptic material for dressings.

Jute.—Jute, also called Indian hemp, consists of the woody fibres of the different kinds of corchorus, particularly the *Corchorus capsularis*, a plant growing in the East Indies and China. It is an excellent substitute for cotton. Mosengeil was the first to use it for making dressings. It very

readily absorbs the secretions from the wound. Jute is often impregnated with antiseptics, such as carbolic, salicylic acid, and bichloride of mercury, and these forms of antiseptic jute are prepared practically in the same way as the corresponding kinds of antiseptic mull or gauze (see § 46). It is best used in the shape of jute pads - that is, jute sewed up in bags of sterilised gauze.

Flax, hemp, seaweed, bran, tow, bark, etc., are used for dressings in the same way as jute, and impregnated with antiseptics or sterilised by subjecting them to steam heat at a temperature of 100° C. (212° F.).

Flax.—Flax is recommended by Medwedew, Makuschina, and others. It is usually made up into small bundles, which are boiled in lye for three hours and then left to stand in the same liquid for eight to ten hours longer. After washing it five to seven times in clean water, the flax is dried and combed, and finally becomes a completely white, soft, and delicate material which is very absorbent, and, like jute, is used in the form of small pads. Flax is about five or six times more expensive than cotton.

Peat.—Neuber recommends peat, having, by chance, observed a compound fracture of the forearm which healed perfectly under softened peat which had been applied to it. Neuber soaks the peat in a 1 to 1,000 solution of bichloride, and fills bags of fine-meshed carbolised or bichloride gauze with it. These pads, made of different sizes, are then used for dressings. One or more layers of sterilised gauze are placed upon the wound; then a small-sized pad of peat; and next, a larger-sized pad. Peat can be easily impregnated with antiseptics, such as iodoform, salicylic acid, etc., and its antiseptic properties are thus increased. Peat also readily absorbs the secretions from the wound. The peat-gauze dressing can be left in place several weeks (four to six weeks) without giving rise to any disturbance.

Peat Cotton.—Redon has made from peat a material like cotton, or rather tow, which Lucas-Championière considers suitable as a dressing for wounds, on account of its softness, its great power of absorption, and its cheapness.

Moss.—Leisrink recommends ordinary moss as a most excellent material for dressings, combining in itself all the advantages which a dressing should possess. It is soft, has great power of absorption, and is cheap. Neuber's peat gauze is, in fact, chiefly made up of moss. The dried moss should be soaked in a solution of bichloride (1 to 1,000–2,000), or made aseptic by subjecting it to steam heat at a temperature of 100° C., and then used as a dressing in a dry state, packed into sterilised gauze bags. The wound is covered with two layers of gauze which have been soaked in a 1 to 1,000–3,000 solution of bichloride, or else sterilised by dry heat, and over these are laid a small and then a large moss cushion. Hagedorn has also recommended moss as a most appropriate dressing. The moss should be collected from the woods, picked apart, dried, and then heated in an oven for several hours at a temperatnre of 105°–110° C. (221°–230° F.). The dried material is then sewed up in sterilised gauze bags, and thus used for dressings in the form of moss cushions. These make an excellent dressing for one which has to be left long in place. The different species of moss were the materials used for dressings in ancient times.

Moss Felt.—Leisrink has recommended tablets of moss felt in the place of moss cushions. The preparation of the felt is as follows: The freshly gath-

ered moss is pulled apart, washed, and then steeped in water, after which it is made into felt and put in a press. According to the greater or less amount of moss used, thick or thin tablets are made which consist of hard or soft felt, depending upon the pressure exerted upon the pulp. The dried felt can be sewed up in gauze bags of different sizes and shapes. Before using, these dry gauze-moss tablets are soaked in a 1 to 1,000 solution of bichloride, and squeezed dry ; or else they are sterilised by steam at a temperature of 100° C., and then applied in the form of dressings. Leisrink also uses the thick, hard tablets as a splint material in compound fractures. Hagedorn's moss pulp and moss-gauze pulp, soaked immediately before use in sterilised salt solution, water, or bichloride, are excellent materials.

Wood Wool.—P. Bruns and Walcher use for dressings wood wool or wood which has been rubbed into small particles by a grindstone. This material has great powers of absorption, is light, soft, and cheap. It can be impregnated with five to ten per cent. of glycerine and 0·5 per cent. bichloride, or with any other desired antiseptic ; or it can be sterilised by steam at a temperature of 100° C. The best wood for the purpose is the *Pinus picea*. Wood wool is packed into gauze bags, and used for dressings in the shape of wood-wool cushions. This dressing is simplified by combining with the wood fibre a twenty-per-cent. admixture of ordinary cotton wool, thus rendering the preparation of wood-wool cushions superfluous. The wood wool dressings are remarkable for their great absorptive powers, and they can be left in place upon large wounds for two to three weeks, and the secretions from the wound will become dry during this time. Moreover, if the dressings on a large wound become saturated with the secretions at the expiration of two to three days, they need not be changed, but simply re-enforced by the addition of wood-wool cushions applied externally. P. Bruns puts on the wood-wool dressing in the following way : The wound is covered first with a layer of sterilised spun glass or gauze, to prevent the dressing from adhering. Over this is placed a small and then a large wood-wool or wood-cotton cushion, and the whole is firmly secured in place by a tight bandage.

Wood Fibre.—Kümmel has recommended wood fibre for an antiseptic dressing material. It is made from pine or fir needles, and forms a dry, green substance made up of fine fibres, and having a pleasant piny odor. Wood fibre is cheap, but does not absorb so readily as other materials. Like moss, it is best to sew it up in gauze bags, and after soaking in sterilised water and squeezing dry, it can be used for surgical dressing.

Sawdust.—All other woody material in a finely divided state, like wood flour and sawdust, are used like wood wool. Mikulicz considers sawdust, particularly when free of sap, a most excellent material for dressings, it being a good absorbent and inexpensive. Sawdust is used for dressings in the shape of pads or cushions, like wood wool or moss.

Wood Wadding.—Rönnberg recommends wood wadding, which is a substance made during the process of manufacturing paper. It is pure cellulose, or a brown, woody material in a finely divided state, which can be readily impregnated with antiseptics. Powders like iodoform or salicylic acid, etc., can be easily mixed with it.

Marly Scraps.—Tolmatschew has recommended marly scraps as an ex-

tremely cheap material for dressings. It is a product in the manufacture of marly or Scotch gauze, and consists of thready scraps made in tearing off tangled threads.

Ash Cushions.—Schede and Kümmel have used pads made of ashes. Coal ashes are freed from the admixture of coarse particles, and, to increase their absorbent power, they are moistened with a little bichloride solution (one part of the bichloride solution to twenty-five hundred parts of the ashes). They are then packed in thin cotton bags which have been previously disinfected by a one-half-per-cent. bichloride solution (with the addition of ten per cent. of glycerine), or sterilized by heating them at a temperature of 100° C. These soft ash cushions adapt themselves very well to the surface of the body, and are excellently suited for exerting pressure.

Paper Wool.—I can recommend paper wool as an excellent absorbent material, and one which forms a soft dressing, very comfortable for the patient. It is made in the manufacture of paper from cloth and is cheaper than mull.

Gedeke uses bichloride paper, or filter paper which has been soaked in a two-tenths-per-cent. solution of bichloride (with five per cent. of glycerine) and then dried.

Maas claims that the absorbent powers of dressings can be increased very perceptibly by the addition to them of such hygroscopic substances as glycerine or common salt, and thus those dressings which have but little power of absorption, such as cotton, tow, jute, etc., can be materially improved, a consideration which would be of much value, particularly during war times.

Glass Wool.—Schede, Kümmel, and others have recommended glass wool as a substitute for Lister's protective. The very delicate fibres of spun glass form a good absorbent, can be easily purified by concentrated acids, and are stored in small bundles in a one-tenth-per-cent. solution of bichloride, from which they are taken, and after gently squeezing them are laid upon the wound in a thin layer. This material keeps the wound, or the suture line, perfectly dry and free from irritation.

§ 46. **The Different Antiseptics.**—Of the various antiseptics which are employed in the treatment of wounds and for dressing purposes, carbolic acid and bichloride of mercury are the most widely used. Carbolic acid is the antiseptic which is most intimately connected with the reform in modern surgery, and was chosen by Joseph Lister from among all the antiseptic drugs known at that time as the best adapted for carrying out his new methods.

Carbolic Acid.—*Carbolic acid* or *phenol* (C_6H_6O) was isolated by Runge, in 1834, from coal tar. It forms colourless, hygroscopic crystals having a pronounced caustic action, which are soluble at ordinary temperatures in fifteen parts of water, and are very poisonous to plants and animals. J. K. Wolf, in 1840, seems to have been the first to recognise the disinfecting powers of carbolic acid, and he was certainly the first to use the drug for medical or surgical purposes. In the fifth and sixth decades of this century carbolic acid was used in dressings by Cruveilhier, Rigault, Maisonneuve, and others, but to Lis

ter belongs the honour of being the first to introduce the drug into general surgical use.

Preparation of Carbolised Gauze.—Carbolised gauze, which was much used at one time, is best prepared by Paul Bruns's method: Five hundred grammes of soft gauze or mull are soaked in a mixture of one thousand parts of alcohol, two hundred parts of rosin, twenty parts of castor oil, and fifty parts of carbolic acid. At the present time carbolic acid, in spite of its poisonous character, is looked upon as one of the best of the antiseptics, particularly for the further disinfection of instruments after they have been boiled for five minutes in a one-per-cent. soda solution. It is ordinarily used in the form of a two-and-a-half- to three-per-cent. aqueous solution for cleansing a wound, disinfecting instruments, for washing out pads or sponges during an operation, for a spray, or for the hands. Gärtner and Plagge have established the fact that a three-per-cent. aqueous solution of carbolic acid will render micro-organisms entirely innocuous. The stronger five-per-cent. solution is used for wounds already infected, but always with caution on account of the danger of poisoning. The five-per-cent. solution should invariably be subsequently washed away by a three-per-cent. solution. Moreover, the five-per-cent. solution is serviceable for disinfecting the field of operation, and for storing sponges, silk, catgut, etc. Laplace has increased the solubility and the disinfecting power of carbolic acid by the addition of crude sulphuric acid; he forms a mixture consisting of twenty-five-per-cent. crude carbolic acid with an equal amount of crude sulphuric acid of a similar strength, and after heating it allows the mixture to cool off. The same result is obtained by the addition of a two-per-cent. solution of hydrochloric acid. At present we avoid washing out a wound with a three- to five-per-cent. solution of carbolic—a practice which was formerly much in vogue—as we now know that it is unnecessary and even dangerous in the case of large wounds. It should always be borne in mind that carbolic acid is a powerful irritant to the tissues, and is, furthermore, poisonous. Children and anæmic and cachectic individuals are particularly prone to carbolic-acid poisoning.

Carbolised Glycerine.—Carbolised glycerine is an excellent disinfectant for instruments and the hands of the operator. It consists of glycerine containing ten to twenty per cent. of carbolic acid, and is useful for disinfecting catheters, sounds, or other blunt instruments, which should in the case of abdominal operations be immersed in it for several hours. We smear the finger with five-per-cent. carbolised glycerine or carbolised vaseline for making a rectal or vaginal examination.

Carbolic-Acid Poisoning.—Carbolic acid is, as has been said, poisonous, and, even when used externally, can produce dangerous symptoms which may terminate in death. I once saw a very rapidly fatal case of poisoning in a student. A friend gave him a teaspoonful of five-per-cent. carbolic acid by mistake, and unfortunately the stomach pump was not used by the physician called in. In another similar case the patient was saved by immediately washing out the stomach.

The symptoms of carbolic-acid poisoning are headache, dizziness, nausea, and vomiting. The change in the colour of the urine to olive green or black is an important symptom in making the diagnosis. But the intensity of the poisoning bears no constant relationship to the intensity of the discolouration of the urine. With even strikingly dark urine the patient may feel very well. The carbolic acid is found in the urine in the form of phenol-sulphuric acid. In the most severe cases there ensue bloody diarrhœa, hæmoglobinuria, and symptoms of collapse, and convulsions caused by the increased reflex excitability of the spinal cord (Salkowsky, Gies.); then follows a marked fall of temperature, the pupils react slowly or not at all, the respiration becomes superficial, consciousness is lost, and death takes place from paralysis of the vasomotor centre in the medulla. In the case of children and weakly individuals, the external application of carbolic acid should be used with great caution. Furthermore, many apparently strong individuals are very susceptible to this drug. In 1878 I lost a woman thirty-nine years old from carbolic-acid poisoning, simply as the result of changing the dressing under the spray ten days after the operation (a laparotomy for fibro-myoma of the uterus). An extensive carbolic erythema over the whole body, accompanied by intestinal hæmorrhage, caused the death of this patient on the twenty-second day after the operation. The post-mortem examination showed perfect union of the operation wound and exceedingly hyperæmic intestines filled with blood. In the early days of the antiseptic treatment of wounds, cases of carbolic-acid poisoning were comparatively frequent.

Billroth, Küster, and Kocher were the first to point out the dangers involved in its external use. Clinically two distinct forms of phenol poisoning are recognised—acute carbolic-acid poisoning, and the chronic, which takes the form of a marasmus (Falkson, Czerny, Küster). The chronic poisoning is characterised by headache, hiccough, debility, and loss of appetite—symptoms which were of frequent occurrence among surgeons who operated very much under the carbolic spray. Falkson assisted at an operation for two and a half hours where a two-per-cent. carbolic spray was used, and in the following twenty-four hours he found 2·06 grammes of carbolic acid in his urine, an amount fourteen times greater than the maximum dose of 0·15 gramme allowed by the Pharmacopœia.

Detection of Carbolic Acid in the Urine.—Millon's reagent (a solution of mercury in ordinary fuming nitric acid) and bromine water give a very useful reaction with carbolic acid after the urine has been previously acidulated with hydrochloric or sulphuric acid and then distilled. Carbolic urine assumes a violet colour upon the addition of chloride of iron, and if warmed with Millon's reagent it takes on a purplish-red colour, or with hypochlorite of sodium a dark-brown colour ; if treated with bromine water a precipitate

of tribromophenol results. A very good reaction for phenol is produced by a hydrochloric-acid solution (hydrochloric acid fifty centimetres, distilled water fifty centimetres, and calcium chloride 0·20 gramme) and a pine stick (Hoppe-Seyler, Tommasi). Tommasi describes it as follows: Equal quantities of urine and ether are shaken together, the supernatant liquid is then decanted and the piece of stick is soaked in it until saturated, when it is plunged quickly into the hydrochloric-acid solution and finally exposed to the sunlight. The ensuing reaction consists in a blue colouration of the stick; but if carbolic acid was not present in the urine there will be no change in colour, or at the most a slight change to a faint green colour. This reaction will enable the slightest trace of carbolic acid to be recognised in urine or water. If the stick is exposed to the sunlight too long, the colour eventually disappears.

The Presence of Carbolic Acid in the Different Organs after Poisoning.—Hoppe-Seyler has measured amounts of phenol contained in the separate organs after phenol poisoning, and he has found that the brain and kidneys hold more than the others, consequently investigation should be first directed to these organs in cases of suspected carbolic-acid poisoning.

Treatment of Carbolic-Acid Poisoning.—The treatment of poisoning from this drug consists in stopping its use immediately—for example, by removing the carbolic dressing. Sonnenburg has recommended the internal administration of Glauber's salts (sodium sulphate) to hasten its excretion through the kidneys in the form of the innocuous sulpho-carbolate of sodium. The sulphate of sodium should be given in large doses by the mouth or rectum, though its efficacy is somewhat doubtful. The rest of the treatment is symptomatic—i. e., the symptoms are treated as they arise, and stimulants and large amounts of water are given internally. If the poisoning is produced by swallowing carbolic acid, the stomach-pump should be used immediately.

Bichloride of Mercury (corrosive sublimate, $HgCl_2$, Hydrargyrum bichloratum corrosivum) is one of the oldest drugs, and, according to Pearson, was known to the Chinese, who have made it from cinnabar from time immemorial. Paracelsus was the first to use it internally, but as an application to wounds it was first recommended by Bergmann and Schede, after Billroth, Buchholz, and R. Koch had found out and made known its excellent antiseptic properties. R. Koch showed that bichloride of mercury, even in the dilution of 1 to 330,000, completely arrested the growth of anthrax bacilli, and in a solution of a strength of 1 to 1,000–5,000 almost instantly killed the anthrax spores. As the bichloride is the most poisonous of all the salts of mercury, it was natural that many surgeons at first would have nothing to do with it in the treatment of wounds. But now it is a great favourite among surgeons, and is almost always used for disinfecting the field of operation, the hands, and the wound, in aqueous solutions varying from 1 to 1,000–5,000. Besides the positive antiseptic power of bichloride it has the advantage of being much cheaper than carbolic acid. I use a one-fifth-

per-cent. solution of bichloride for the storage of silk (after boiling it half an hour in a one-fifth-per-cent. bichloride solution) and of catgut which has been sterilised by the method already described. Bichloride is unsuitable for the disinfection of instruments, as we have seen, and for these I use a three-per-cent. solution of carbolic acid. Schede and I both use a one-tenth- to a one-twentieth-per-cent. solution of bichloride when we wish a powerful disinfectant, and a one-fiftieth-per-cent. solution when a weak one.

Stability of Bichloride Solutions.—If ordinary water, which has not been distilled, is used for making bichloride solutions, an insoluble compound of mercury will separate after a time, which, according to Fürbringer, is a trioxychloride, or a dioxychloride, or a tetraoxychloride, and is thrown down by the alkaline carbonates in the water. For preventing this precipitation of the bichloride which occurs in ordinary spring water, Fürbringer recommends the addition of acids (salicylic, hydrochloric, and acetic acids, 0·5 to 1 gramme per litre); Laplace recommends tartaric acid (one part bichloride, five parts tartaric acid); while Bergmann and Angerer recommend common salt (one gramme sodium chloride to one gramme bichloride of mercury). These acid and common-salt solutions of bichloride of mercury are exceedingly good on account of their great stability, and are always to be preferred to plain bichloride solutions. The bichloride tablets containing bichloride and ordinary salt, and recommended by Angerer, are very useful for private and military practice. They consist of either one gramme or half a gramme of bichloride of mercury and chloride of sodium. Schillinger, Fürbringer, and V. Meyer have demonstrated that the stability of a bichloride solution depends especially upon whether the vessel in which it is contained is air-tight or not, and also upon the amount of exposure to light, as light and air tend to weaken the strength of the solution.

Preparation of Bichloride Gauze.—Bichloride gauze, which has been used much more in the past than it is now, is made by saturating gauze with a mixture of ten parts of bichloride of mercury, five hundred parts of glycerine, ten hundred parts of alcohol, and fifteen hundred parts of water. This makes a mixture which is sufficient to saturate about sixty to seventy metres of gauze, which should be dipped into it and then dried. Ordinarily gauze containing one third per cent. of bichloride answers sufficiently the purposes of an antiseptic dressing. Cotton, jute, etc., can also be impregnated with bichloride in the same way. Instead of using dressings which have been impregnated with bichloride of mercury, we now employ materials which have been sterilised by steam heat at a temperature of 100° C., because it has been

proved that dressings impregnated with antiseptics are, after a time, no longer sterile but contain bacteria (Laplace, Schlange, etc.).

Bichloride Poisoning.—As we have previously remarked, *bichloride of mercury* is a *dangerous poison*, and must be used with very great caution, especially in the case of children and sickly individuals. The symptoms of poisoning manifested after the external exhibition of the drug consist in a feeling of dizziness, restlessness, general malaise, vomiting, salivation, ulcerative stomatitis of the gums, and toward the last there is a bloody diarrhœa and occasionally bleeding from the mouth and nose. The urine contains mercury and albumen. Locally, when the bichloride dressing has been applied, there is sometimes an eczema, with persistent itching and burning of the skin, particularly if the dressings have been put on too wet, and this should therefore be avoided. It is necessary, moreover, to use bichloride of mercury carefully in the interests of the physician and of the assistants. Even then they will occasionally show signs of poisoning in the form of salivation and inflammation of the gums, or mercury and albumen will be present in the urine. I have never yet seen dangerous symptoms of poisoning occur in patients whom I have treated myself, and only now and then slight stomatitis and eczema. Since asepsis has taken the place of antisepsis in operations, and we have limited the use of bichloride, the cases of poisoning from this drug, like those from carbolic acid, have become much less common. One should operate as "dry" as possible, and avoid irrigating and washing out the wound with bichloride solutions whenever this can be done, and use only dressings which have been sterilised by steam, etc. Operations in the thorax, peritoneal cavity, rectum, and vagina must be conducted with very great care as regards the use of bichloride, and the latter should not be employed for washing out the pleural cavity after an operation for empyema, nor for irrigating the uterus or rectum, etc.

Bichloride Poisoning from very small Amounts of Bichloride.—Fatal cases of bichloride poisoning are sometimes caused by very small amounts of the salt. Thus Mikulicz lost a female patient fifty-six years old who otherwise was apparently sound, after amputating the breast and clearing the carcinomatous glands out of the axilla. In this case the bichloride was only used in the dressings, which consisted of sawdust cushions containing one per cent. of bichloride of mercury. There was a severe dermatitis, followed after the second day by restlessness, vomiting, a thin, bloody diarrhœa, and bleeding from the nose and mouth accompanied by inflammation of the gums (gingivitis). No mercury was detected in the urine. Stadfeldt also lost a primipara twenty-three years old, from washing out the interior of the uterus with a 1 to 1,500 solution of bichloride, which was done for fever occurring five days after confinement. After about three hundred grammes

had been used the patient complained of headache and pain in the hypogastrium. Two hours afterwards there was sweating, weakness, and vertigo, followed a few hours later by bloody diarrhœa, albumen in the urine, vomiting, ulceration of the tongue, etc. There was no abdominal pain. On the fourth day there was complete anuria and cyanosis, followed on the fifth day by death. The post mortem showed marked swelling of the cortex of both kidneys, ulcerations in the colon with a very hyperæmic mucous membrane, and similar lesions in the small intestine. Microscopically the epithelium in the convoluted tubules of the kidneys was granular and swollen, and in many places showed marked fatty degeneration, and there were numerous hyaline casts. Similar lesions, though less pronounced, were found in the straight tubules. The spleen was small, the liver normal, and mercury was present in all the organs (liver, kidneys, brain).

Treatment of Bichloride Poisoning.—The treatment of poisoning by bichloride of mercury consists in immediately stopping its use; the rest is symptomatic—i. e., treatment of symptoms as they arise.

Salicylic Acid.—Salicylic acid ($C_7H_6O_3$) exists in the form of small needle-shaped crystals, which are odourless, and only slightly soluble in cold water (1 to 300–400), but readily soluble in hot water, alcohol, ether, or glycerine. Salicylic acid is not volatile like carbolic acid, from which it is made synthetically by treating carbolate of sodium with carbonic acid gas at a temperature of 150° C. By the absorption of carbonic acid the basic sodium salt of salicylic acid results, and the former treated with hydrochloric acid produces salicylic acid.

Kolbe was the first to make salicylic acid in this way, and Thiersch then introduced it into surgery. Aside from its internal administration, salicylic acid is extensively used in surgery as a dusting powder for wounds (Schmidt), in solution (1 to 300) for the disinfection of wounds, and particularly for continuous irrigation, and in disinfecting ointments (one part acid salicyl., six parts cera alba, twelve parts paraffine, twelve parts almond oil). As salicylic acid is not so poisonous as carbolic acid, it forms an excellent substitute for the latter in cases where there is reason to fear the use of carbolic or bichloride. Salicylic acid should be used with caution as a dusting powder for wounds which are liable to absorb large quantities of it, since fatal poisoning has thus been produced. Schmidt saw two cases of death where the powder had been employed very freely, and though death was not to be ascribed to the effects of salicylic acid alone, it nevertheless had certainly contributed towards the fatal termination.

Boro-Salicylic Solution.—Bosc has made the very practical suggestion of adding borax to the salicylic solutions, thus increasing the solubility of the salicylic acid without decreasing the effectiveness of its action. A very excellent solution for the antiseptic irrigation of wounds consists of one part salicylic acid, six parts of borax, and five hundred of water—cotton and jute impregnated with three and ten per cent. of salicylic acid were formerly much in vogue, but at present they are being employed less and less, like all other materials saturated with antiseptics and used for dressings.

Acetate of Aluminium.—Acetate of aluminium, like all the salts of acetic

acid, is a very good antiseptic (Pinner) ; Burow, senior (1857), was the first to use it with success. He prepared the substance from a mixture of eight parts acetate of lead, five parts alum, and sixty-four parts water, the acetate of lead being slowly added to the cold alum solution. This precipitated sulphate of lead, leaving the acetate of aluminium, though not chemically pure, in solution. The solution should then be filtered. Since his time acetate of aluminium has been used as an antiseptic with the best results by a great many surgeons, especially for continuous irrigation of wounds and for saturating wet dressings (H. Maas). For continuous irrigation a one-half- to one-per-cent. aqueous solution is the best.

Aceto-tartrate of Aluminium is an easily soluble double salt having a strong antiseptic action, and has been recommended by Schede and Kümmel as an antiseptic in a one-half- to three-per-cent. solution for external antiseptic applications, and in a three- to five-per-cent. aqueous solution for the disinfection of wounds, especially in cases where carbolic acid cannot be used on account of its poisonous properties.

Thymol, a non-poisonous substance, is the active principle of oil of thyme, which is obtained from various species of thyme, particularly the thymus vulgaris. In 1719, Neumann isolated from oil of thyme a crystalline, camphor-like body which he called thymol. The crystals are sparingly soluble in water, but readily soluble in alcohol and ether. Thymol has been recommended by Bouillon, Paquel, Ranke, and others as a suitable antiseptic for applying to wounds.

Thymol is used in an aqueous solution in the strength of 1 to 1,000, containing, in addition to the water, ten parts of alcohol and twenty of glycerine to prevent the precipitation of the thymol. This solution can be used for the disinfection of instruments, sponges, hands, and particularly of the wound. Thymol gauze is prepared by mixing together sixteen parts of thymol, fifty parts of resin, five hundred parts of wax, and one thousand of gauze.

Chloride of Zinc.—Chloride of zinc has been much used by Campbell, De Morgan, and Billroth, and lately by Kocher, for antiseptic dressings and for disinfecting wounds. The experiences of different authors with the drug vary very much. Billroth thinks that only caustic solutions of chloride of zinc are of antiseptic value ; but Kocher, after a great many experiments, has reached the conclusion that even very weak solutions (2 or 2½ to 1,000) in dressings are sufficient for maintaining a wound aseptic ; other surgeons use chloride of zinc solutions in the strength of 1–3 to 100. In 1879, Bardeleben recommended dressings which were first soaked in such a solution and then dried before being applied ; thus, jute was saturated with a five- and ten-per-cent. solution of chloride of zinc and allowed to dry. But it has not come into anything like universal use in the treatment of wounds, and is chiefly employed as a caustic in about an eight- to ten-per-cent. solution to cleanse fistulous tracts, foul ulcers, etc.

Boric Acid.—Boric acid (H_3BO_3) exists in the form of flat crystals, which are only slightly soluble in cold water (1 to 30), but readily soluble in hot water and in alcohol. It is usually employed in a two- to three-per-cent. solution, though for irrigation of wounds aqueous solutions of a strength of 5–10 to 100 may be employed. Boric acid is much used in the form of Lister's boric lint, a dressing which is non-irritant and yet strongly antiseptic ;

it contains equal parts by weight of boric acid and lint, and is applied to the wound in a dry or wet state. Boric lint is very simply prepared by soaking lint in a hot concentrated boric-acid solution; it is then allowed to dry, causing the boric acid to adhere firmly to the lint in the form of crystals.

Boric Ointment.—An excellent ointment is made with boric acid consisting of three parts boric acid, five parts vaseline, ten parts paraffine ; or three parts boric acid, four parts cera alba, and twenty parts olive oil. A simpler and more stable mixture is one of twenty parts of boric acid with one hundred parts of vaseline or ungt. glycerini (known as glyceritum boroglycerini). As a general thing boric acid is a mild antiseptic, but if used too freely it may not be devoid of danger. Molodenow used a five-per-cent. solution very freely for washing out the pleural cavity in one patient and a lumbar abscess in another, and in both cases uncontrollable vomiting resulted, followed by erythema of the face, and death from cardiac paralysis. He used an excessive amount (15 kilogrammes) of a five-per-cent. solution, continuing the irrigation for as much as an hour.

Aseptin.—The so-called aseptin used in Sweden is a mixture of two parts boric acid, one part alum, and eighteen parts of water ; it is less irritating than carbolic acid, is not poisonous, and has no unpleasant odour.

Tetraboride of Sodium.—The tetraboride of sodium (Jaenicke) is more soluble and effective than boric acid, and on account of its non-irritant and non-poisonous character can be used in a fifteen- to seventy-per-cent. solution.

Bismuth.—Bismuth (subnitrate of bismuth) is a white, crystalline powder of an acid reaction, which is only slightly soluble in water, and is recommended by Kocher for treating wounds and for antiseptic dressings. Its antiseptic properties had been already praised by Cloquet, Velpeau, etc. Bismuth lessens the secretion from a wound very perceptibly, but it is not an innocuous substance, as symptoms of poisoning have been produced when used in strong mixtures (ten per cent.) or in large amounts; these are acute stomatitis with marked swelling of the gums, tongue, and throat, and a dark discolouration of the edges of the gums, as in lead poisoning, diarrhœa, nephritis accompanied by albuminuria, and, finally, dark-coloured urine. On account of the possibility of poisoning, Kocher uses only a one-per-cent. bismuth mixture. When inflammatory processes develop about a fistulous tract I have found it a good practice, after first scraping out the fistula with a sharp spoon, to irrigate it thoroughly with a five-per-cent. bismuth mixture.

Iodoform.—Iodoform (CHI_3) is a bright yellow crystalline powder, almost insoluble in water, acids, and alkalies, but readily soluble in ether, chloroform, alcohol, volatile oils, and fats. About 2·5 to 3 grammes of iodoform are soluble in one hundred grammes of olive oil. It was first introduced in 1853, and since 1866 has been highly recommended as a dressing for wounds, particularly in syphilitic cases; but to Moleschott, and especially to Mosetig-Moorhof, belong the honour of introducing iodoform, in 1880, into general surgical use, and thus enriching our methods of dressing wounds by a most valuable remedy. There is scarcely a material which is so extensively employed and

which gives such general satisfaction as iodoform. But the enthusiasm for iodoform waned somewhat when cases of poisoning terminating fatally had been recorded. I also, I am sorry to say, have had two cases of fatal iodoform poisoning following an extirpation of a goitre and removal of a carcinomatous larynx. Many surgeons then went to the opposite extreme, and expressed the hope that iodoform would disappear as soon as possible from all use in medicine on account of its very poisonous character. At present we always employ iodoform with great care, particularly if the patient is aged or anæmic or cachectic, or is a child, or has a diseased heart or kidneys. But even perfectly sound individuals may have an idiosyncrasy as regards iodoform, and very small amounts may produce symptoms of poisoning. I very seldom use iodoform as a dusting powder for fresh wounds, and then only in small amounts. It should be applied by a brush or by a pulverising apparatus, or blown over the wound, or dusted over it through a piece of gauze, so that the surface in question is only lightly covered with iodoform. I consider it unnecessary to dust iodoform over a wound which has been sutured. It is very useful in injuries and operations affecting the nose, throat, mouth, vagina, and rectum, for syphilitic and tubercular ulcers, and for many cases of compound fracture. P. Bruns and myself have obtained excellent results from the injection of a ten-per-cent. iodoform mixture in glycerine or oil, in cases of bone and joint tuberculosis and in cold (tubercular) abscesses. The drug has a marked antitubercular power, as proved by P. Bruns, Nauwerck, and B. Tilanus. Senger recommends the addition of formic acid to iodoform to increase the efficacy of the latter. The proportions are as follows: Iodoform 2·0, glycerine 20·0, sodium formate 0·5 to 1·5 (for adults, 3·0). According to Senger, iodoform only derives its power from the formic and hydriodic acids and other decomposition products of iodoform set free by oxidation within the body. Iodoform gauze is exceedingly useful, consisting of iodoform 50, ether 250, alcohol 750, and gauze 500 parts; or iodoform 50, resin 20, glycerine 5, and alcohol 1,000 parts. It is particularly valuable for packing cavities, but must be used with great care in the class of individuals mentioned above, as I have seen symptoms of poisoning after the use of iodoform gauze alone—for example, after extirpation of the rectum; and particular care must be taken not to exert too much pressure in the bandages applied over a wound which has been packed with this gauze. Billroth's sticky iodoform gauze is best suited for cavities where mucous membrane exists, because it adheres firmly to the surface of the wound. It is made by wringing out six metres of gauze or mull in a solution consisting of 100 grammes of resin, 50

grammes of glycerine, and 1,200 grammes of alcohol (95 per cent.), and after the gauze has dried, 230 grammes of iodoform are rubbed into it.

Iodoform Wicks.—Gersuny uses an iodoform wick instead of iodoform gauze, and prepares it in the same way as the latter, which has the disadvantage of having many loose threads along its cut edge, which may be left in the wound and retard healing. The strand of wick is also more easily conducted out of the wound through an opening in the skin. An attempt may be made to conceal the very sharp, saffron-like odour of iodoform by the addition of tincture of musk, bergamot oil, tonka bean, or powdered coffee. The coarse crystalline substance should always be employed, and not the fine powder. The iodoform dressing should be left in place, according to the nature of the case, from two to four to eight to fourteen days. Though iodoform, particularly during the first years of its use, produced not infrequently fatal intoxications, it has seldom been the cause of any poisonous symptoms worth mentioning since we have learned the necessity of using it with caution.

Iodoform Drainage Tubes.—The impregnation of drainage tubes with iodoform has been recommended ; they are soaked for about an hour in a concentrated solution of iodoform in ether and then allowed to dry. Iodoform is much used in the form of iodoform collodion (1 to 10), which is used in place of the ordinary sticking plaster. Sticks of iodoform gelatine are now used for fistulæ, chronic gonorrhœa, and similar troubles. Mosetig recommends a fifty-per-cent. iodoform glycerine injection for goitre and for soft hyperplastic lymphomata. Iodoform sticks are prepared in the following way : Iodoform ten parts, gum arabic, glycerine, and pure starch each one part. This mass is then rolled into slender rods or sticks. They can be more simply made by mixing together one part of iodoform and two parts of cocoa butter. We shall return to this subject later on in its proper place.

Effect of Iodoform upon Bacteria.—Kronecker, Heyn, Rovsing, and others, showed that the streptococcus and staphylococcus pyogenes aureus, as well as other bacteria, may live a week in iodoform powder unharmed, and that therefore iodoform must be disinfected before it is used. But if we must admit that iodoform has no direct influence over the bacteria, we nevertheless know that it renders harmless the ptomaines (toxine) of various bacteria, or rather that it decomposes the ptomaines into harmless compounds (De Ruyter, Behring). Neisser showed that iodoform is decomposed by bacteria, and that it then has an antiseptic action. Of these decomposition products free iodine and hydriodic acid are the most important. The more pronounced the putrefaction and decomposition in a wound, the more pronounced becomes the antibacterial action of iodoform (Neisser). E. di Mattei and A. Scala also insist that iodoform and iodol only act through decomposition and the setting free of nascent iodine. Iodoform is, strictly speaking, not an antiseptic, as Schnirer has shown, but it still remains a valuable drug when combined with some antiseptic, on account of the power it possesses of dimin-

ishing both pain and the secretion from a wound. According to De Ruyter, the iodoform-ether-alcohol solution (1 to 2 to 8) is an excellent antiseptic. C. B. Tilanus has demonstrated that iodoform prevents, or at least checks, the development of tubercle bacilli, and even has a tendency to destroy them, though slowly and in no very active manner.

Iodoform Poisoning.—Schede, König, Czerny, Kocher and others, have described the *symptoms of iodoform poisoning* as usually taking the form of cardiac and cerebral disturbances, particularly in the more severe cases. Cardiac symptoms are usually the first to make their appearance. The milder cases of poisoning are characterized by a rapid, irregular, small pulse; by digestive and slight nervous disturbances, such as anorexia, nausea, and finally vomiting; by headache, general malaise, sleeplessness, a depressed frame of mind, etc. In the more severe cases of iodoform poisoning the symptoms may correspond to either one of the two following descriptions, in which we agree with König:

(*a*) The pulse suddenly becomes rapid and small; there is sleeplessness, great restlessness, delirium, hallucinations, maniacal excitement, and melancholia, with refusal to take food. These symptoms of mental aberration can be quickly checked by removing the iodoform dressing, but they may be prolonged for weeks even after the iodoform has been stopped. Some of these cases terminate fatally from cardiac and respiratory paralysis.

(*b*) After a brief period of excitement there follows a general paralysis of the central nervous system, giving the picture of a severe meningo-encephalitis (loss of consciousness, deep sleep, coma, involuntary discharge of urine and fæces, accompanied by great muscular relaxation). This is the more severe form, and nearly always terminates fatally.

Occasionally there is observed a papular or, more commonly, an urticaria-like eruption on the skin. Observations upon the occurrence of fever vary. Schede has seen it often, others (König, Kocher, and myself) have noticed it less frequently. The pulse is regularly greatly accelerated. The length of time that may elapse between the application of the iodoform dressing and the first symptoms of poisoning varies very much. Sometimes marked symptoms come on during the very day of the operation; in other cases three to five to six days, or even fourteen days, pass before they make their appearance. Iodoform poisoning is generally acute, but sometimes it takes a chronic or subacute course, and the symptoms may persist several weeks, although the drug is suspended at the very first appearance of intoxication. Mikulicz saw one case terminate fatally after the expiration of twenty-nine

days. König's statistics seem to show that, of all the cases of poisoning that he could collect up to the present time, the greater number were in individuals advanced in years. Of thirteen severe and fatal cases, nine were in people over fifty years of age. In old people the strength of all the organs, particularly the heart and kidneys, is impaired, and these organs in consequence succumb more readily to the influence of poisons. According to König, children are the least susceptible to this danger.

Explanation of Iodoform Poisoning.—To explain iodoform poisoning we must, of course, know in what form iodoform enters the body and in what form it is excreted. At the point where it comes in contact with the tissues iodine is split off and is absorbed into the blood as an alkaline iodide and an albuminate of iodine (Högyes, Zeller, Harnack). The albuminate of iodine decomposes in the system, forming organic substances containing iodine, which are excreted in the urine together with the alkaline iodides. According to Harnack and Ludwig, the general symptoms of iodine poisoning are, in fact, chiefly produced by the iodine in the form of an albuminate of iodine, or by the organic compounds of iodine. It is well known that the alkaline iodides can be introduced into the system in very large amounts without causing the general symptoms of iodine poisoning. Zeller claims that only a fractional part of the iodine is excreted in the urine and fæces while the rest remains in the system; and thus he explains how iodoform poisoning may sometimes first make its appearance after the expiration of two to three weeks. If iodine is already present in the system, iodine poisoning is the more liable to occur when iodoform is applied externally at the same time. If this substance is then employed in too large amounts, and circumstances favour its absorption, and if there is diminished excretion of iodine on account of disease of the kidneys or heart, while the blood is both qualitatively and quantitatively deficient, under such circumstances poisoning is apt to make its appearance rapidly and to run an acute course, terminating in death. As a means of preventing to a certain degree this general poisoning of the whole system, Harnack takes the precaution of applying with the iodoform some harmless alkali in the locality where the former is used, so as to favour the formation of an alkaline iodide from the free iodine which is split off from the iodoform.

From the reasons just given it is plain how iodoform poisoning is produced by dressings which exert pressure, or by those which, together with the iodoform, are frequently renewed, and especially by the use of large amounts of the substance when the kidneys are healthy, or small amounts when they are diseased. Mosetig-Moorhof, in his large experience, has never seen a single case of iodoform poisoning, attributing it to the fact that he never uses iodoform except in small amounts, never applies dressings in which it exists so as to exert pressure, and changes them as infrequently as possible and without irrigation of the surface of the wound. He also considers it dangerous to use carbolic acid simultaneously with iodoform in dressings, because the carbolic acid may produce an inflammation of the kidneys amounting to an actual nephritis (nephritis carbolica),

and thus retard the excretion by the urine of the iodoform which has been absorbed, or, in other words, cause it to be retained in the blood. These statements of Mosetig-Moorhof are confirmed by the experiments of Holger Mygind, who found that in all cases in which iodoform and carbolic acid were used together the iodine reaction was given in the urine rather later than usual, the longest time necessary for it to appear being twenty-seven hours after ingestion, the shortest four hours, or the iodine was detected in the urine only after all traces of carbolic acid had vanished. Moreover, Holger Mygind claims that the albuminuria that appears during the use of iodoform is only produced by the simultaneous use of carbolic acid. It is of some practical value to note that the excretion of iodine is continued for a considerable length of time after the use of iodoform has been suspended; for instance, one gramme of iodoform gave rise to a reaction for iodine for twenty-two days, and fifteen grammes gave the iodine reaction in the urine for thirty-eight days, etc. The size of the wound has a great influence upon the rapidity of the absorption of iodoform. Granulating wounds absorb it more quickly than fresh wounds, and wounds in which fat is abundant take it up very rapidly. According to Binz, the iodoform is dissolved by the small particles of fat.

As we have before remarked, iodoform produces marked cerebral and cardiac disturbances, having a narcotic effect upon animals (dogs and cats), and causing death by paralysis of the heart and respiration (Binz, Hagyer). Aschenbrandt brought about a fatal pneumonia by causing animals to inhale iodoform vapour. The post-mortem examination in these cases revealed advanced fatty degeneration of the heart, liver, and kidneys. Post-mortem examinations of the human subject dying from iodoform poisoning reveal a similar fatty degeneration of these organs, and in addition either no change in the brain or an œdema of the pia mater.

Treatment of Iodoform Poisoning.—Besides the immediate removal of the iodoform dressing, *the treatment of iodoform poisoning* is purely symptomatic. In the worst cases no treatment has proved of any avail. Very alarming symptoms are apt to make their appearance suddenly without any prodromata. It is impossible to state the smallest amount of iodoform which may be used with impunity, as the dosage varies for each individual and depends on all the circumstances above enumerated. One gramme of iodoform has been known to produce a transient delirium; and Seeligmüller observed melancholia with hallucinations thirty days after the administration of six grammes of iodoform; and five grammes caused the death of one of his cases, a woman thirty-six years of age. I lost one case in which a goitre was removed, and another in which a carcinomatous larynx was extirpated, in each of which cases I employed about five grammes of the powdered drug together with the iodoform in the iodoform gauze used for packing the wound. In still another case, a strong man fifty years of age, I saw alarming symptoms follow a simple dusting of the suture

line which remained at the termination of the laparotomy, with four to six grammes of iodoform; stupor, great restlessness, maniacal excitement, rapid, small pulse, etc., were present, but after four weeks complete recovery took place. Of course the dressings were removed at the very first appearance of the symptoms. The poisoning was doubtless caused by the excessive sweating to which the patient was subject during the hot days in July. In general, five to ten grammes of iodoform will produce no marked disturbances in patients between twenty and forty years of age who are otherwise healthy. The fine powder seems to be more readily absorbed and is therefore more dangerous than the coarse crystalline substance (Güterbock). Not infrequently, however, thirty to forty to eighty grammes of iodoform, and even more, have been employed. It is not to be wondered at that fatal poisoning followed in some cases the use of such large amounts.

Detection of Iodine in the Urine.—For detecting iodine in the urine there are the following four methods:

1. The fluid to be tested is mixed with a little starch paste, dilute sulphuric acid, and a drop of fuming nitric acid, after which there results a bluish colour, which may change into dark blue according to the amount of iodine present. This colour disappears on warming the mixture, and reappears when it has cooled off again.

2. The fluid is mixed with dilute sulphuric acid and a drop of fuming nitric acid, and then shaken with chloroform, in which the iodine is soluble, producing a violet colour. Chloride of lime can be used instead of the nitric acid, and bisulphide of carbon instead of chloroform.

3. Upon the addition of equal parts of oleum terebinthinæ and guaiacol to an equal amount of urine there results a deep-blue colour if iodine is present.

4. To the fluid is added a little starch paste, dilute sulphuric acid, fuming nitric acid, and a few drops of bisulphide of carbon. The fluid assumes a blue colour, and, if shaken, a part of the iodine is taken up by the bisulphide of carbon, producing a violet colour, and where the bisulphide of carbon touches the rest of the fluid a dark-blue ring of the iodide of starch gradually develops.

According to Harnack, this last test is the most delicate; but all these reactions are directly dependent upon the presence of iodine in the urine in the form of an alkaline iodide (iodide of sodium, etc.). He claims that iodine derived from the external use of iodoform occurs in the urine not only as an alkaline iodide, but also as a compound with organic substances, and in the latter state does not give the above reactions. Harnack noticed in two cases that the test for iodine in the urine was negative; but if the urine was evaporated and the residue burned, the ashes gave a very plain iodine reaction. His method is as follows:

The urine is rendered alkaline by the addition of sodium somewhat in excess, and evaporated in a platinum crucible in which the residue is then burned by heating the crucible red-hot. The carbonised ash is then re-

peatedly treated with hot water and the resulting extracts are filtered. To the filtrate is then added a few drops of dilute starch paste and fuming nitric acid, together with a few drops of bisulphide of carbon. When the solution is acidulated with dilute sulphuric acid the presence of iodine is indicated by a blue colour; when shaken, the bisulphide of carbon lying at the bottom takes on a violet tint, and just above it there forms a dark-blue ring of the iodide of starch. To recognise the difference between the intensity of the reaction obtained from the ash and from the urine, the former must be mixed with a volume of water equal to the amount of the original unevaporated urine, and then the reaction is carried out with equal quantities of this mixture and of urine.

Ciamician, Mazzoni, Pick and others have recommended iodol as a substitute for iodoform; Perrier and Patin, salol made from carbolic and salicylic acids; Siebel and A. Petersen, europhen, which contains 28·1 per cent. of iodine; and Eichoff has recommended aristol, which is a compound of iodine with thymol. Aristol has no odour and is non-poisonous, and is particularly useful in the treatment of various skin diseases. Pallin saw a case of iodol poisoning after the use of five grammes of this substance in a sequestrotomy of the clavicle. Salol should be given internally with caution, on account of the phenol it contains; Hesselbach observed a death follow the administration of eight grammes of this drug, which parted with about 3·04 grammes of carbolic acid in the body.

Dermatol is an excellent non-poisonous substitute for iodoform, and much used in the treatment of skin diseases. Those of the newer antiseptic powders which are worthy of mention are diiodthioresorcin, sulphaminol, and sozoidol (*Hydrargyrum sozoiodolicum*, Tromsdorff). The latter non-poisonous powder is used in the form of a one-per-cent. emulsion in glycerine, gum arabic, and water as an ointment for treating catarrh, etc. Peroni and Bovus recommend euphorin in the place of iodoform.

Of the remaining antiseptic substances, of which there are a great number of considerable merit, I shall briefly mention the following:

Naphthalin.—Naphthalin ($C_{10}H_8$) was isolated from coal tar by Gardener in 1828. It forms large, shining, colourless, crystalline plates of a tarry odour and a burning taste. It is insoluble in water, readily soluble in hot alcohol, ether, volatile and fixed oils. It burns with a bright, sooty flame.

E. Fischer especially has recommended it as an antiseptic for the treatment of wounds. Naphthalin is dusted over a wound in the same way as powdered iodoform. In my own experience I have found naphthalin a most excellent disinfectant. A foul wound will quickly clean up after dusting it with naphthalin, and the process of granulation is accelerated. Sometimes its use is accompanied by pain, which may be so great in susceptible persons that its further employment has to be discontinued. Naphtha-

lin possesses all the advantages of iodoform without having any poisonous action.

Benzoic Acid.—Benzoic acid crystallises in the form of thin plates or needles, which are only slightly soluble in cold (1 to 500) but readily soluble in hot water (1 to 30), and in alcohol, ether, and concentrated sulphuric acid. Benzoic acid is usually employed in solution in the strength of 1 to 200.

Sulpho-carbolate of Zinc.—Bottini (Pavia) has recommended sulpho-carbolate of zinc as an antiseptic. It forms large, white, transparent, odourless, rhomboidal crystals, which are readily soluble in distilled water, alcohol, and other liquids. Bottini considers the sulpho-carbolate of zinc better than all other similar antiseptics. It has the great advantage of being absolutely non-poisonous. It is employed in two- to ten-per-cent. solutions.

Alcohol.—Dressings of alcohol have been used since the most ancient times, and were in great repute even in Heister's day. In France, and perhaps in England, this liquid finds its most extensive use, but in Germany it is no longer employed. Fifteen- to twenty-per-cent. solutions have been used for washing out wounds and for disinfecting instruments, sponges, etc. According to Hack, it has the effect of rendering granulations which have been treated with it incapable of absorbing anything.

Terebene.—Terebene ($C_{20}H_{16}$) is a brownish, oily fluid with a pleasant, aromatic odour, insoluble in alcohol, ether, water, etc., but soluble in all proportions in oil. It is much used, particularly in England, for the treatment of wounds, either in the undiluted form for badly granulating, foul, gangrenous wounds, or diluted with equal parts of oil for the saturation of dressings, or else it is mixed with water (30 to 500) and used for irrigation purposes.

Eucalyptus.—Eucalyptus is a volatile oil having a strong antiseptic action, and is made from the leaves of the myrtaceæ, a tree growing in Belgium, Italy, and the south of France (the *Eucalyptus globulus*). It has been recently recommended by Schultz as an excellent non-poisonous antiseptic. The commercial article is very variable in quality, and Schultz advises that the oil be treated with soda until its acid reaction becomes neutralised, and then be exposed in sunlight to the action of the oxygen in the air, which causes the oil to lose its pungent odour and become non-irritating when used in dressings. The oil of eucalyptus can be mixed with alcohol and water, 0·2 to 0·3 per cent., and then used as a fluid in which to wring out compresses. Lint which has been soaked in a solution of one part oil of eucalyptus and ten parts olive oil can be used for applying to wounds.

Iodine.—The antiseptic properties of iodine, tincture of iodine, the solution of iodine in an aqueous iodide of potash solution and of iodine vapour, have been proved by countless experiments. In recent times, in England and America, the solution of iodine—i. e., iodine two parts, iodide of potassium three parts, and water forty-eight parts, has been much used for dressings, lint being steeped in this mixture. The combination of this iodine solution with laudanum is also highly spoken of. For cleansing wounds, Bryant recommends iodine water (one part tincture of iodine to 75 to 100 of water).

Other Antiseptics.—There are still to be mentioned alum, quinine, chloral (1 to 4 per cent. in water), chloroform water (Salkowski), chloride of lime, carbonate, acetate, and chloride of lead, acetic acid, permanganate of potas-

sium (from 1 to 100–1,000), camphor and the spirits of camphor, glycerine, sulphate of zinc, citric acid, trichlorphenol (Dianin, Popoff, etc., one- to ten-per-cent. solutions), turpentine, tar, peroxide of hydrogen (2 to 12 volume aqueous solution), sulphuric acid and the sulphates and subsulphates of the alkalies, picric acid, resorcin, balsam of Peru, common salt solutions, carbon, powdered coffee, naphthol (soluble in the proportions of 1 to 5,000 parts of water, but rendered more soluble by adding alcohol), tannic and chromic acids, bichromate of potassium, aseptol (two to ten per cent.), and aseptin acid (a five- to ten-per-cent. solution of aseptin acid), etc.

Of the numerous other antiseptics recently brought to notice the following may be spoken of :

Trichloriodine.—Langenbuch recommended trichloriodine (1 to 1,000–1,500) as practically devoid of danger, and as a suitable material for the disinfection of the instruments, hands, the field of operation, sponges, etc., and he tested it in a great number of cases. In germicidal power it stands next to bichloride of mercury (Riedel).

Creolin.—Jeyes, its discoverer (1875), Kortüm, Fröhner and others recommend creolin in a one- to two-per-cent. solution, which, according to Henle, is a mixture of soap, oil of creolin, phenol, and pyridin ; it combines the useful properties of bichloride of mercury and iodoform without their poisonous effects. Creolin is an oily, dark-brown fluid, smelling of tar, and is made by the dry distillation of coal tar, forming with water a milky emulsion which has a threefold more powerful action than carbolic acid, and is used in a one- to two-per-cent. solution. Esmarch has given fifty grammes of creolin to animals internally without causing any bad effects. Behring, Baumgarten, etc., maintain that creolin has no such germicidal properties as carbolic acid or bichloride of mercury, and that it is more poisonous than has been hitherto supposed. In severe cases of creolin poisoning—for example, after the internal administration of large amounts—there occur loss of consciousness, albumen and blood and renal epithelium in the urine, enlargement of the liver, and jaundice (van Ackeren).

Peroxide of Hydrogen.—Love recommends peroxide of hydrogen (two- to three-per-cent. solution), but it is rather expensive, and on account of its unstable character it is unsuited for an antiseptic.

Rotter's Antiseptic Solution.—Rotter has combined a great number of antiseptics in one solution. To one litre of water are added bichloride of mercury 0·05 gramme, sodium chloride 0·25 gramme, carbolic acid 2·0 grammes, chloride and sulpho-carbolate of zinc, each 5·0 grammes, boric acid 3·0 grammes, salicylic acid 0·6 gramme, thymol 0·1 gramme, and citric acid 0.1 gramme. The ingredients of this solution are also combined in tablet form, and called "Rotterin." Rotter also left out of this solution bichloride of mercury and carbolic acid, and considers that the remaining ingredients have a stronger antiseptic action than one-tenth-per-cent. solution of bichloride alone. Von Baeyer has demonstrated that all these different antiseptics combined in the one solution do not undergo any change.

Aniline Dyes.—Stilling recommends the aniline dyes for antiseptics in the form of an aqueous solution of (pyoktanin, Merk.) methyl violet (1 to 1,000), but its value has not been confirmed by others (Carl, Jaenicke, Petersen, etc.).

Lysol.—Lysol in one fourth- to two-per-cent. aqueous solution, manufac-

tured by Schülke & Mayer, in Hamburg, is an excellent and relatively non-poisonous antiseptic, and is recommended by Engler, E. Schmidt, Gerlach, etc., and has been much used in operations. On account of its cheapness and its non-poisonous character lysol is very well adapted for disinfecting and cleansing purposes, instead of carbolic acid.

Salveol.—Salveol (Hammer, A. Hiller), a cresol compound (neutral aqueous solution of creosol) in 0·5-per-cent. solutions, has a more powerful antiseptic action than five-per-cent. carbolic solutions, and it is, furthermore, comparatively non-poisonous.

Ichthyol.—Ichthyol is extensively used in the treatment of various skin diseases. Latteux commends the antiseptic effect of five- to ten-per-cent. solutions for irrigating purposes.

Alumnol.—Alumnol (Heinz, Liebrecht) is a white powder which is highly recommended for the treatment of skin diseases and gonorrhœa, and in one-half- to five- to ten-per-cent. solutions for the disinfection of cavities, abscesses, infected wounds, ulcers, etc.

§ 47. **Which Antiseptics and which Antiseptic or Aseptic Dressings are the Best?**—Which antiseptic amongst the great number which are recommended is the most powerful and at the same time the best adapted to the treatment of wounds? My own experience places carbolic acid and bichloride of mercury at the head of the list for certainty in action, and, if used with caution, particularly in the case of children and cachectic individuals, they are also devoid of danger. If one uses carbolic and bichloride in the proper way he will see no more cases of poisoning from their employment. For aseptic operations common salt solutions or simply sterilised water may be used. Amongst the other antiseptics the ones which I consider the best are boric acid, acetate of aluminium, creolin, lysol, salicylic acid, iodoform, oxide of zinc, naphthalin, chloride of zinc, and bismuth. The method of their application has been sufficiently described above.

Which antiseptic or aseptic material is the best for dressings? Their number is almost without limit, and the choice, as we have remarked, is more or less a matter of taste. But the great principles involved remain the same, namely, that the operation must be conducted with the strictest attention to asepsis; that the arrest of the hæmorrhage, the drainage, and the suturing of the wounds should all be carried out with the greatest care. The main point to be aimed at in the application of a dressing is that the secretion of the wound should be well provided for; and this is excellently fulfilled by the dry gauze or mull dressing, and also by the dressings made of moss, wood wool, jute, my own special wool prepared for dressings, and similar materials. Moss, wood wool or excelsior, jute, etc., are covered with sterilised gauze and applied in the shape of sterilised pads or cushions. All materials used for dressings should be sterilised by steam at a temperature of 100° C.

for twenty to thirty minutes in a steam sterilising apparatus. Dressings which have been impregnated with antiseptics become after a time less aseptic, and, furthermore, produce irritation of the skin and cause an eczema (see pages 3, 4). My own method of applying a dressing is very simple, and is ordinarily done as follows: The wound, or the suture line, is covered with several layers of sterilised gauze; over this is placed cotton, or pads or cushions of jute or moss which have been sterilised by steam at a temperature of 100° C. (212° F.). In private practice I cover the wound with gauze folded into several layers which has been dipped in a 1 to 1,000 solution of bichloride and wrung dry, and over this I apply a layer of cotton or of my prepared wool. The less the wound is irritated by antiseptics, or, in other words, the dryer the operation, so much the less is the subsequent secretion from the wound, and there is consequently less need of dressings having great absorptive powers like moss pulp, wood wool, etc.; gauze covered with absorbent cotton or jute cushions will be all that is required.

To favour the drying of the secretion from the wound within the dressings the gutta-percha or mackintosh should be avoided, except in the case of young children, when some water-tight substance should be employed to prevent the dressings from becoming soiled by urine, fæces, etc. All the dry antiseptic dressings are much better than those of the wet antiseptic, occlusive variety, as the latter are apt to occasion an eczema frequently lasting a good while, and increase the danger of poisoning, particularly from carbolic acid and bichloride of mercury. But, as we shall see, wet dressings in the form of continuous irrigation are most excellent for cases of extensive suppuration (see pages 178, 179). I never apply antiseptic dusting powders, like iodoform, bismuth, salicylic or boric acids, to a wound which has been closed by sutures. This powder dressing is chiefly suited for wounds which have not been closed by sutures and for those which are granulating or suppurating. For these I always employ iodoform when possible, but only in very small amounts. But at present I very seldom use powder dressings, and content myself with packing the wound with iodoform gauze. Open wounds—that is, those which have not been sutured, like one resulting from extirpation of the uterus and from a joint resection for extensive tubercular inflammation, etc.—are best treated by packing with iodoform gauze, and after the expiration of two to four days the packing is taken out and the aseptic wound is closed by secondary sutures. I attach great importance to the use of a moderate amount of pressure upon the wound, particularly after the extirpation of tumours, by small moss cushions, or by gauze which has been shaken

out and crumpled up into pads. Antiseptic sponges have also been employed with good results for exerting pressure on wounds. For an ointment I prefer boric acid mixed with vaseline, or else plain vaseline alone. If it is necessary to disinfect an already infected wound, I use solutions of bichloride of mercury (1 to 1,000 – 5,000).

The antiseptic and aseptic dressings should be as large as convenient, though I do not consider this now of as much importance as I used to. For applying the dressing the patient should be placed in the most suitable position. For bandaging the head, shoulder, and thorax the patient should be made to assume a sitting posture, while for the abdominal region a cushioned prop (Fig. 117) is placed under the patient's hips while the latter are held by an assistant. Splints of wood, sheet metal, plaster of Paris, or wire, etc., serve to immobilise an extremity (see § 53). For less serious cases thin, pliable wooden hoops are exceedingly useful. One of the great advantages of the antiseptic and aseptic methods of treating wounds lies in the fact that the dressing requires much less frequent renewal than formerly, when the unsatisfactory occlusive dressing was employed.

These general remarks on the technique of antiseptic or aseptic dressings will suffice at present, and the particular way of dressing this or that variety of operative or traumatic wound will be described in the

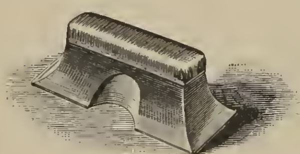

FIG. 117.—Support for the pelvis (Volkmann).

FIG. 118.—Aseptic dressing for the scalp.

FIG. 119.—Aseptic occlusive dressing for the head, neck and breast.

Text-Book on Special Surgery. Figs. 118 and 119 illustrate two methods for applying an aseptic dressing to the skull and the head, neck, and chest. The particulars are given in § 50.

§ 48. **The Changing of an Antiseptic or an Aseptic Dressing.**—When shall an aseptic dressing be changed? In the first place, the nature of the case and the kind of operation or injury must be considered.

In general it has been my experience that a change of the dressing is called for under the following conditions:

1. When the temperature rises above 38·5° C. (101·3° F.).
2. When the dressing becomes soiled from without—for example, by urine or other excretory matter.
3. When the patient is suffering severe pain.
4. When the dressing becomes displaced or loosened, or when the secretion from the wound saturates the dressing to such an extent as to be apparent externally.

Whenever fever occurs—and I make a regular practice of considering any rise of temperature above 38·5° C. (101·3° F.) under this heading—I change the dressing, and am pretty sure to find that there is either some slight disturbance in the wound, a retention of the secretion, or a stitch which is too tight, etc. As a general thing, in my own operations I have very seldom observed any rise in temperature above 38·4° C. (101° F.). Other surgeons have noticed a rise of temperature of several degrees during the healing of a perfectly aseptic wound. Volkmann and Genzmer, especially, have made investigations upon this fever and have called it the "aseptic wound fever." I have very seldom seen the aseptic wound fever, and when a rise in temperature does occur while the healing process is going on it will usually be found to take its origin from some perceptible abnormity in the wound. Opinions vary as to the cause of this aseptic wound fever. Volkmann and Genzmer consider it an absorption fever produced by the entrance into the general system of the relatively homologous products of metabolism and disintegration which are formed in every wound. Sonnenburg and Küster believe that aseptic wound fever is caused by carbolic-acid poisoning. Both of these views are of use in explaining the phenomena. My own view of the aseptic wound fever leads me to believe that it is caused by the absorption of lymph and the fibrin ferment from the blood lying in the wound. This fibrin ferment is formed the more abundantly the more the wound has been irritated by carbolic acid or other strong antiseptic solutions. I believe I am not mistaken in affirming that all surgeons who make free use of solutions of bichloride, carbolic, or other irritating antiseptics in their treatment of wounds, will frequently notice aseptic rises in temperature, while those surgeons who are cautious in their use of antiseptics, and prefer asepsis to antisepsis, will only observe this phenomenon in a few exceptional cases. Many surgeons—Neuber, for in-

stance—have recommended that the dressing be allowed to remain undisturbed in such instances of aseptic fever, claiming that a change of dressing only creates further disturbance in the wound and is consequently harmful. I cannot agree to this statement, though I seldom have to do with fever following an operation. If it does occur, I always change the dressing as a matter of course, if the temperature rises above 38·5° C. (101·3 F.), and I usually find, as I have said, some slight variation from the normal in the healing process. I prefer to change the dressing as infrequently as possible, and I am particularly careful to avoid irritating the wound by excessive irrigation, washing out, etc. It can only do harm.

From what has been said so far, we can readily understand the importance of ascertaining a patient's temperature in the morning and evening, or, in more important cases, three to four times a day, or even every two hours, and it is best taken in the rectum. I prefer, if there is fever, to change the dressing too frequently rather than allow one to remain too long. If the discharge should soak through the dressings, they can still be left undisturbed, if only the external layers remain dry and no fever is present.

My rules for changing an antiseptic dressing are as follows: If the wound is extensive, and there is considerable discharge, I change the first dressing after the expiration of twenty-four to thirty-six hours, even though there is no rise in temperature; or I allow the first antiseptic dressing to remain undisturbed till the end of the third to the fourth to the eighth day, according to the nature of the case. Drains are removed at the end of the first twenty-four hours, or on the second to the third day, the stitches generally on the third to the fifth day. After a laparotomy which runs a normal course without reaction, I change the first dressing on the eighth to the twelfth day, according to the size of the abdominal wound, and at the same time I remove the stitches, though if the wound is under considerable tension a stitch here and there is left in place for a little while longer.

An aseptic dressing should be changed only with the strictest attention to the rules of antisepsis, and everything which is required for the dressing, particularly the pieces of gauze, the bandages, etc., is to be prepared in advance in the proper manner. The instruments, such as scissors, probes, forceps, etc., should be boiled in a one-per-cent. soda solution and placed in a three-per-cent. solution of carbolic acid; the sponges or gauze pads should lie in a one-tenth-per-cent. solution of bichloride. The hands are to be disinfected with the greatest care (see page 9). The dressing is then slit up with strong bandage scissors (Fig. 120), or the bandage is unwound, and after it has been thor-

oughly washed, disinfected, and sterilised by steam at 100° C., it may be used again as a non-antiseptic bandage; but it is a better plan to burn all dressings immediately after they have been taken off. I never use the spray now.

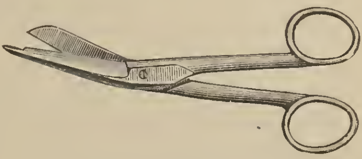

FIG. 120.—Dressing scissors.

After removing the bandages and superficial portions of the dressing, the hands are again disinfected by dipping them into a three-per-cent. solution of carbolic or 1 to 1,000 bichloride, and after this the portion of the dressing lying in contact with the wound is removed as carefully as possible. If it adheres to the skin or to the wound, it should be softened by squeezing out upon it a few drops of the antiseptic solution from a sponge. The wound is then examined by pressing here and there very lightly with the index and middle fingers to ascertain whether there is any retention of the secretion, and finally the drains, stitches, etc., are removed. If the healing process is progressing normally in every respect, there should be no syringing out or washing off of the wound, and all that is necessary is simply the application of a fresh dressing. The forcing of antiseptic solutions through the drainage-tubes is particularly to be avoided, as it always does harm, and I never indulge in this practice except when suppuration is present, and then only rarely. If the drains become occluded by blood-clots and are to remain in the wound, they should be made pervious by passing a probe through them; or, better still, they should be taken out of the wound, washed in a three-per-cent. solution of carbolic or 1 to 1,000 bichloride, and finally reinserted with a safety pin attached to them to prevent them from slipping into the wound, or else entirely new drainage-tubes may be employed. Very often a stitch which is cutting into the tissues or is drawn too tight must be removed at the end of twenty-four to thirty-six hours. The presence of swelling and redness indicates a retention of the secretion, which should then be let out by one or more incisions with the knife, with or without subsequent drainage. If there is an appreciable amount of suppuration it may be necessary in some cases to change the dressing every day for a time, or to substitute for the antiseptic occlusive dressing some other simpler kind. Should erysipelas occur, the antiseptic occlusive dressing can be maintained.

Even when the wound remains uninterruptedly aseptic, bacteria are commonly found in the antiseptic or aseptic dressings. These bacteria belong chiefly to the non-pathogenic species of skin coccus, and do not interfere with the normal process of healing. If the staphylococcus

pyogenes aureus and the streptococcus are found, there will probably be a disturbance in the wound, but the presence of the staphylococcus pyogenes albus only exceptionally causes an infection of the wound (Tavel., O. Lang, A. Flach). Dressings which have been allowed to remain in place a long time will give off a bad odour not unlike old cheese, caused ordinarily by the decomposition of sweat and sebaceous matter. Not infrequently there will be found an eczema, especially if wet carbolic or bichloride dressings have been used, and this is best treated by the application of vaseline or the ungt. lithargyr. Hebræ,* and by dusting it over with bismuth and starch (1 to 5–10), or oxide of zinc and starch (1 to 5–10), or by applying Lassar's paste (oxide of zinc and powdered starch āā 10, salicylic acid 1, vaseline 20). Such eczemas can be best avoided by the use of simple, sterilised, dry dressing materials.

If the wound has healed there is generally no further need of any dressing. In other cases it may be necessary to cover granulating areas or drainage-holes with some ointment like boric-acid ointment, or by sticking plaster, iodoform collodion, or with iodoform, zinc oxide, or bismuth powder, or with a piece of simple dry gauze or cotton. I very often allow an aseptic material which has become dry to remain on the wound like a scab, with or without a protecting bandage. After a time the aseptic scab drops off and the wound is found to be healed.

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* Unguentum diachylon.

CHAPTER II.

OTHER METHODS OF TREATING WOUNDS.

The old-fashioned protective dressing.—Open method of treating wounds.—Healing beneath a scab.—Antiseptic bathing.—Immersion.—The use of warm baths.—Cataplasms.—Poultices.—Cold.—Ice.—Lister's cooling apparatus.—Adhesive substances (sticking plaster, gauze adhesive plaster, English plaster, collodion, photoxylin, traumaticin, gummi laccæ).—Ointments.

§ 49. **Other Dressings for Wounds.**—The old-fashioned protective dressings of sticking plaster, charpie, ointments, etc., are no longer used at the present day, and after operations we now cover the wound, without exception, with antiseptic or aseptic dressings, though in the case of small fresh wounds, or those which are granulating, we occasionally employ adhesive plaster, collodion, iodoform collodion, and antiseptic salves, boric-acid ointment, for example.

Open Method of treating Wounds.—The open method of treating wounds is the simplest one of all. Small superficial wounds are now allowed to go without any dressing, especially when the blood and secretion from the wound becomes dried and thus forms a protecting crust beneath which the wound heals.

Healing beneath a Scab.—The healing under a scab, which occurs in small wounds, has been made the basis of a separate method of treatment, in which an attempt is made to form a scab artificially over wounds having an abundant secretion by the application of dry substances, such as tinder and various kinds of powders, or a dry eschar is made by some strong caustic, like nitrate of silver, liq. ferri sesquichlor., the hot iron, etc. All these different ways of accomplishing the same result, if carried out with no antiseptic precautions, even though the wound be small, are not devoid of danger. But the modern surgeon never fails to treat every wound, including the very smallest, upon antiseptic principles, because we know that even the most insignificant lesion in the skin, under certain conditions, may cause a septic cellulitis or an erysipelas which can prove fatal. On the other hand, Schede's method of treating wounds by permitting a moist aseptic blood-clot to remain (see page 102) is to be looked upon as a real advance in this branch of

surgery. As above stated, it is an excellent plan to permit the dried dressings to remain upon the wound like a dry aseptic scab, until they come away of their own accord when the wound has healed.

This open method of treating wounds yielded relatively excellent results in the preantiseptic days of surgery, even when used for large wounds, such as amputations, disarticulations, compound fractures, etc., and was practised till supplanted by the antiseptic dressing.

In the open method of treatment the wound was not provided with any dressing, but left entirely exposed, or only lightly covered with antiseptic compresses. It was not closed with sutures until later on, when a few coaptation sutures were used. In this way the escape of the secretion from the wound was favoured. If the wound was situated on an extremity the latter was placed in a proper position to facilitate the escape of the discharges, which were received in a vessel or bowl placed beneath. The crusts which formed in the wound, from dried blood or secretions, were softened and removed by means of antiseptic solutions or by carbolised oil. The principal advantages in the treatment of a wound by the open method were a ready escape of the secretions, complete rest which was undisturbed by change of dressings, and finally absence of pressure. It had the disadvantage that wounds healed slowly and only after suppuration.

In cases where the antiseptic occlusive dressing is no longer advisable on account of suppuration, or a threatening systemic infection, when it may even become dangerous from the pressure it exerts, the open method of treating wounds, particularly in conjunction with continuous antiseptic irrigation, is now in very general use, and is an exceedingly valuable means of handling these cases.

Antiseptic Bathing.—For continuous antiseptic bathing of a wound, or, in other words, for continuous irrigation, such antiseptic solutions should be used as involve no danger to the patient from their absorption and produce no symptoms of poisoning. Of these, the best are three-tenths-per-cent. solutions of salicylic acid ; the boro-salicylic solution (1 part of salicylic acid, 6 of borax, and 500 of water); or solutions of one tenth per cent. thymol, four per cent. boric acid, two per cent. acetate of aluminium, or, what is the best solution of all, viz., Burow's (described on page 159), consisting of ten per cent. subsulphate of sodium, one tenth per cent. permanganate of potassium, lysol, etc. The wound is covered with a light gauze compress. The patient is made to assume a suitable position, and protected by means of watertight coverings and also by properly regulating the overflow of the irrigation fluid. The solution is made to drip from an Esmarch irrigator placed in some elevated spot, or from an improvised irrigator, such as an inverted champagne bottle from which the bottom has been partly removed (Fig. 123), or the excellent apparatus of Starcke may

be used (Fig. 122). Fig. 121 illustrates the proper position for the upper extremity when continuous antiseptic irrigation is employed. Starcke's apparatus consists of a vessel for holding fluid which is connected by a rubber tube with a lead or glass pipe; this is fitted with numerous outlets also connected with rubber tubes which can be opened or closed by stop-cocks or clamps, and by means of wires in their interior can be bent and turned in any desired direction. The lead or glass pipe is suspended from some beam or support by a couple of strings.

If Esmarch's irrigator or the inverted champagne bottle are used as in Fig. 123, the fluid is made to escape in drops or in any required amount by means of a stop-cock placed at the point of insertion of the rubber tube. If the tube is not fitted with one, the outflow of fluid can be regulated by a clamp, or a piece of cotton, or a few strands of jute stuffed into the lumen of the tube, or by a straw, etc.

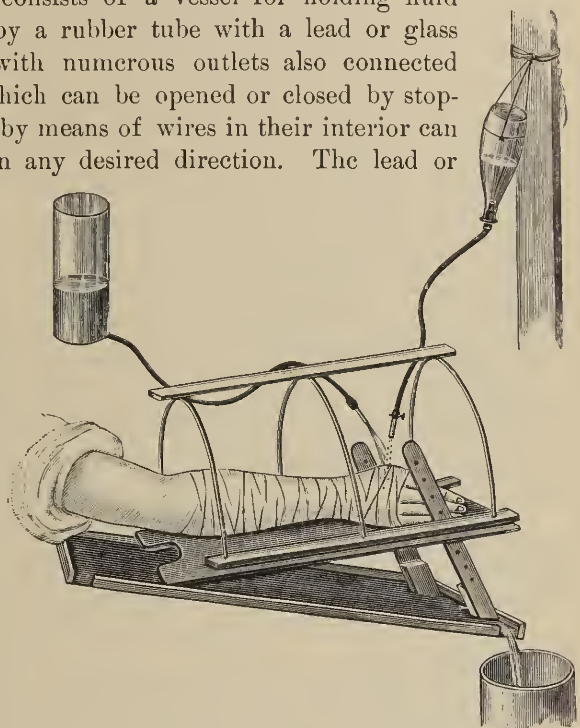


Fig. 121.—Position of the upper extremity during permanent antiseptic irrigation.

Immersion.—Immersion, or bathing the whole body, or separate portions of it which have sustained an injury, were endorsed principally by Langenbeck as a method of treating wounds. The continuous immersion of a patient's whole body in a warm bath day and night is adapted especially for extensive burns, cellulitis, bedsores, and for the after-treatment of operations on the rectum, bladder, urethra, etc. The bath tub is usually made to contain a framework of wood or metal fitted with slats and a movable head-piece which can be raised or lowered. Covers are laid over the frame and an air cushion on the head-

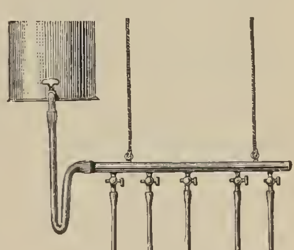


Fig. 122.—Starcke's apparatus for the irrigation of a wound.

piece, and thus the patient is made very comfortable. The patient can be placed on an ordinary sheet instead of a frame, and in this way can be raised or lowered in the tub. The temperature of the water must not be allowed to become too cool, and it is best to regulate it according to the wishes of the patient, and therefore it is a good plan for him to be able to regulate the temperature of the bath himself by turning on or letting out the water. The temperature of the water must usually be maintained at 37° to 38° C. (98·6° to 100·4° F.), and perhaps more, and of course the patient, while asleep, should be watched very carefully by a nurse.

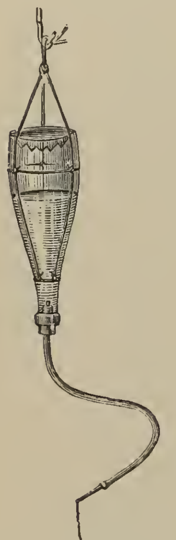


Fig. 123.—Improvised apparatus (irrigator) for the irrigation of a wound.

Influence of a Continuous Bath on a Wound.—The influence of prolonged baths of this kind upon a wound is in general very favourable. The granulations usually swell considerably, and it occasionally happens for this reason that the escape of the discharges is rendered difficult, causing retention and burrowing of pus and phlegmonous inflammations. Nevertheless, the freely granulating surface is apt to become covered with skin very rapidly, and the parts surrounding the wound become soft and yielding. For regulating the growth of the granulations, irritant substances, like spirits of camphor, etc., have been added to the bath, or the wounds have been dressed with them. If the bath becomes too cold there is a possibility of necrosis taking place here and there in the skin; and care should be taken in subjecting old people to prolonged baths on account of the danger of pulmonary, cardiac, or cerebral disturbances.

The use of baths for separate portions of the body which have been injured needs no further description.

The Use of Continuous Baths for Operative Cases and Long-Continued Suppuration.—At the present time, Sonnenburg is a prominent advocate of permanent baths for operative cases and for all patients who are afflicted with long-continued suppuration, and upon whom the ordinary form of antiseptic applications cannot be used, either on account of the peculiarities of the wound or other local conditions, or on account of some idiosyncrasy of the patient. Sonnenburg has practised this method in operations in the pelvic region, in lithotomies, extirpation of the rectum and uterus, urethrotomy, intestinal operations, for bedsores, burns, extensive cellulitis, etc. Many patients can be kept for months in a bath at a temperature of about 30° C. (99·5° F.). The wound drains readily, and accidental wound diseases do not occur. Sonnenburg's description of this bath will be found in the Archiv. für klin. Chirurgie, Bd. 28, p. 921.

Cataplasms.—Warm poultices, either dry or wet, were much used in the treatment of wounds during the preantiseptic days. Fomentum, a hot, wet application, or a fomentation as it is called, is derived from *foveo*, to warm. Cataplasm, or poultice, comes from the Greek word καταπλάσσω, to lay on. Fomentations in a dry form are applied to the wound in the shape of hot cloths, or of finely powdered and chopped-up herbs or vegetable matter, such as bean meal, bran, flores sambucci, etc., either directly or after being sewed up in linen or flannel bags, etc. Cataplasms or poultices are made of boiled linseed meal, groats, etc., which are wrapped in gauze or linen cloth before applying. The ancients used a great number of herbs of various sorts as applications for wounds, and evinced a strong preference for cataplasms prepared in urine or from the excrement of different domestic animals. In the time of Aribasius a paste of figs and milk was much in vogue on account of its antiseptic action. At present, however, cataplasms are not considered proper for the treatment of wounds, and we only use them when we desire to promote suppuration in tissues which are infiltrated with inflammatory matter. The preparation of poultices is very tedious. The hot poultice is renewed by warming the wet cushion upon a hot plate, or in vessels made for the purpose with double walls between which the water is placed to supply the moisture, and the vessel is then heated over a gas or spirit-lamp flame. For doing away with this slow process there have recently been invented artificial cataplasms about the weight of thin pasteboard. These are soaked in hot water and applied to the diseased portion of the body and covered over with some water-tight substance and then with cotton. They afterwards swell and assume a pulpy consistency. A mustard paper is also manufactured which has a very irritant effect upon the skin.

Antiseptic Poultices.—The application to wounds of wet antiseptic poultices of mull, gauze, lint, linen, etc., in a cold or hot form is even at the present time much used in the treatment of suppurating wounds which are granulating. The lead-water poultice is also regarded with a good deal of favour, and I consider it a better application than the irritating one made with carbolic acid. The latter is sometimes used too strong by the laity, and also changed too frequently. I have repeatedly seen gangrene of the skin on the tips of the fingers caused by carbolic acid applied in this form. If wet applications of this kind are to be left in place for some time, possibly one or two days, and the effect of moist heat is desired, the applications should be covered with rubber tissue over which cotton is laid, and the whole dressing is then fastened in position by a bandage (hydropathic poultice or Priessnitz's poultice). Wet dressings like these, particularly if made with lead-water, have a powerful stimulating action upon granulations, and the skinning-over process is occasionally very much hastened. If cold is aimed at in the wet applications, for reduction of the heat in any given portion of the body, the applications will need very frequent renewal.

Cold—Ice.—In such cases it is best to use ice in rubber or ice bags,

or to add ice or snow to the water used for wetting the poultices; or else make a cooling mixture consisting of one part ammonium chloride, three parts of nitre, six parts of vinegar, and twelve to twenty-four parts of water (Schmucker).

The effect of ice and cold applications upon the wound is both analgesic and hæmostatic. Lately, Leiter, of Vienna, has invented an apparatus for obtaining in the most satisfactory manner the effect of cold and heat upon inflamed and injured portions of the body. It consists of a pliable metal tube through which water at any required temperature is allowed to flow. The metal tube can be made to assume any desired form, such as a cap for the head, or a coil for encircling an extremity, or a flat piece for the back, etc. A similar apparatus has been made of rubber tubing, and used as a cold coil for an extremity, an ice cap for the head, or an ice bag for the neck.

Sticking Plaster.—We now treat small wounds, or those which are granulating, by means of a covering of sticking plaster, collodion, some ointment, etc. Adhesive plaster is made of some substance like linen, cotton, silk, leather, etc., covered upon one side with some such sticky material as litharge, olive oil, resin, or turpentine, etc.; lead plaster is made with certain hard substances—oil, wax, turpentine, etc. The ordinary German adhesive plaster is usually warmed over the flame of a spirit lamp before being applied, and then laid in strips upon the desired portion of skin, which has been previously dried. To prevent the plaster from adhering to the hairs, the latter must be first shaved off with a razor.

American Adhesive Plaster.—A very good kind of sticking plaster, though somewhat expensive, is the American adhesive plaster (Ellis's adhesive plaster cloth), in which the sticky material is spread on muslin, linen, or silk.

English Adhesive Plaster.—The English plaster adheres very well and is useful for small wounds; it consists of fine sarcenet having on one side a solution of isinglass and on the other tincture of benzoin (*Emplastrum adhesivum anglicum*). The sticky side should be moistened with some antiseptic solution and not with saliva, and then applied to the skin.

Paris Plaster.—The Paris plaster is more flexible and adheres even better. The recently invented iodoform plaster consists of iodoform, glycerine, and mucilago gummi arabici, which is made into a solution and spread over linen.

There are many other kinds of adhesive plaster which may be found in the Pharmacopœia.

Gauze Adhesive Plaster.—Unna has introduced a very excellent

gauze adhesive plaster, made of oxide of zinc or iodoform spread on gauze with some sticky substance, and it is often preferable to the ordinary adhesive plaster.

Collodion.—Of the other adhering materials I should mention especially collodion, which is a solution of gun cotton in ether and alcohol. By the evaporation of the ether and alcohol the collodion dries in the form of a firm covering which adheres excellently to the skin. It is not suitable for applying to fresh wounds on account of the irritation it causes. Iodoform collodion (1 to 10) is frequently used as a protective dressing, and it is far better than adhesive plaster in that it does not come off by contact with water. A cutaneous wound, after it has been sutured, is frequently painted over with iodoform collodion (Küster, Zweifel, Hans Schmidt), and heals like any wound sutured aseptically, over which there forms a dry aseptic scab. Collodium elasticum (collodion 60, castor oil 2·5, turpentine 7·5) is particularly suited for chapped hands, frost-bites, etc.

Substitutes for Collodion.—As a substitute for collodion I use a bismuth paste—i. e., a solution of bichloride to which bismuth has been added, or zinc glue (oxide of zinc and gelatine āā 20 parts with distilled water and glycerine āā 80·0 parts). These dry rapidly and form an excellent covering for sutured wounds, as well as for small, unsutured, fresh, or granulating wounds.

Photoxylin.—Wahl has recommended photoxylin in place of collodion. It is a substance used in photography, and he employs it in a five-per-cent. solution in equal parts of alcohol and ether.

Traumaticin.—Traumaticin, or a solution of gutta-percha in chloroform, is widely employed as an adhesive dressing in place of collodion.

Gummi Laccæ.—Gummi laccæ (Mellez) is also much employed as a substitute for collodion and English adhesive plaster. A solution of the consistency of jelly made by adding alcohol is warmed and spread on cloth, thus forming a cheap and serviceable adhesive plaster which is not attacked by water or fat, etc.

Salves.—Ointments as dressings for granulating wounds do not enjoy the popularity which they once did, and I rarely use them. I prefer, even for granulating wounds, antiseptic dressings, such as sterilised gauze with or without the addition of antiseptic powders like bismuth, oxide of zinc, iodoform, or similar substances. There are a great number of ointments of which the principal ones are boric-acid ointment, boroglycerin lanolin (Graf), vaseline, salicylic vaseline, carbolised vaseline and glycerine, ointments either pure or mixed with various antiseptics, and, in addition, oxide of zinc, lead ointments, etc. An excellent base for making ointments is the lanolin recommended by Liebreich in which bacteria cannot grow. Glycerine fats, on the other hand, become easily rancid under the influence of light, and then become a good medium for the growth of micro-organisms (Fränkel, Gottstein).

Mollin.—Kirsten recommends mollin as an adjuvant to grey mercurial and iodine ointments.

Pasta cerata.—In conclusion, pasta cerata may be mentioned (Schleich), which can be used in a variety of ways as a dressing for wounds.

CHAPTER III.

GENERAL RULES FOR THE APPLICATION OF BANDAGES AND RETENTION APPLIANCES.

The different kinds of bandages.—The application of the ordinary roller bandage.—The "reverse."—The removal of bandages.—The rolling of bandages.—The application of bandages to particular parts of the body (head, neck, trunk, upper and lower extremities).—The application of retention appliances to different portions of the body.

§ 50. **Application of Bandages.**—The ordinary bandages are made of linen, flannel, webbing, or gauze, etc. For bandaging wounds, as we have said before, we preferably employ sterilised mull or stout gauze, which are first soaked in a 1 to 1,000 solution of bichloride or a three-per-cent. carbolic solution, squeezed dry, and then applied to the selected portion of the body in a damp condition, thus making a well-fitting and strong permanent dressing, as illustrated in Figs. 118 and 119, on page 152.

The rubber bandage, made from ordinary caoutchouc, or the bandage of elastic webbing is used when it is desired to apply a dressing to exert pressure. Elastic bandages are adapted for application about the thorax, the abdomen, etc., where other bandages become easily displaced and loosened. There are both single and double roller bandages, the latter being illustrated in Fig. 124; triple and quadruple rollers were formerly much in vogue, and can be easily made by fastening together a couple of ordinary bandages. The many-tailed bandage, as it is called, consists of several strips of bandage overlapping laterally and joined in the centre by a single cross strip.

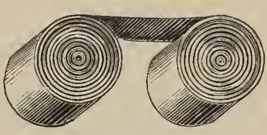


Fig. 124.—Double roller bandage.

Application of the Roller Bandage.—The ordinary roller bandage is applied by holding the end of the bandage upon the desired spot with the index finger or thumb of the left hand, while the roller is directed upward (Fig. 125). The first turn of the bandage is secured by a second, making two thicknesses of the bandage at the one place; then

the bandage is unrolled spirally upwards about the part, making each upper turn overlap about half of the width of the one next below. I usually wind the bandage from left to right. If it is desired to rapidly secure a dressing in place, each spiral turn may be separated by a considerable distance from the next lower turn (Fig. 126), and subsequently the bandage may be completed in the regular way. If one attempts to apply a linen or gauze bandage, for example, to the upper or lower extremity, with circular or spiral turns, it will soon be noticed that the lower edge of each turn does not fit tightly to the extremity, and that its "set," particularly in the case of the forearm and leg, is uneven. For preventing this looseness of the lower margin of each turn, and to make the whole bandage fit evenly and firmly, it is customary to make what is called a "reverse," which is best done as follows (Fig. 127): 1. The roller is grasped by the right hand in such a way that one looks into the palm of the hand, the dorsal surface is directed downwards, and the bandage drawn tight and smooth obliquely upwards, while its lower edge is held firm by the left thumb (Fig. 127, *a*). 2. The traction on the obliquely directed portion of the bandage beyond the left thumb is then relaxed (Fig. 127, *b*). 3. The upper edge of the bandage is then folded over downwards (Fig. 127, *c*). The points of reverse should, as far as possible, be made at the same part of the circumference of the extremity, and lie one above the other. This method should be employed not only in

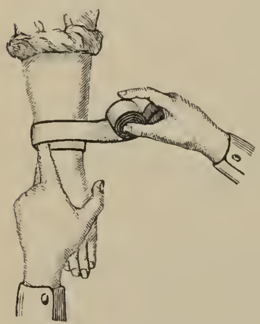
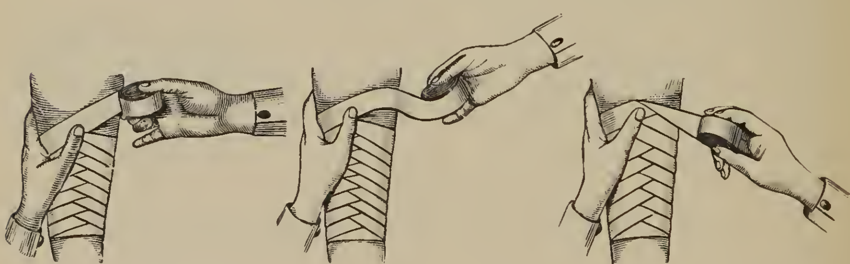


Fig. 125.—Application of the ordinary roller bandage.

Fig. 126.—Spiral bandage.



a *b* *c*

Fig. 127.—Application of the reverse bandage.

bandaging an extremity, but any other portion of the body, so as to make the turns of the bandage fit into the inequalities of the particular locality. The bandage is usually completed by one or two circular turns. While making the reverses care should be taken that ridges and folds are not allowed to form. Considerable practice is necessary in order to be able to put one on quickly and accurately. The end of the bandage should be fastened in place with a safety-pin, or it may be slit up at the end with scissors, or simply torn lengthwise in the middle, if it is a muslin or gauze bandage, and the split ends carried around the extremity in opposite directions and knotted together.

A bandage is taken off by unwinding the turns in the reverse direction to which they were put on—i. e., the turn last applied is the first to be taken off. At the same time the bandage is rolled up, and during the unwinding is quickly passed from one hand into the other. The removal of a mull or gauze bandage is generally accomplished by simply slitting it up with bandage scissors.

In Fig. 128 is illustrated the method of rolling a bandage. Mull and gauze bandage rolls are best and most rapidly made by means of a small rolling machine.

Application of a Bandage to the Head.—The method of applying bandages to the head is illustrated in Figs. 129–132.

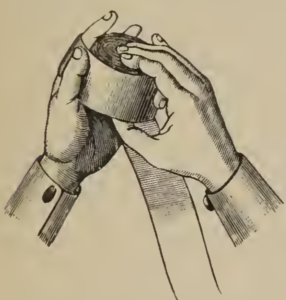


Fig. 128.—Rolling a bandage.

Fig. 129.—Fascia nodosa.

Fig. 130.—Mitra Hippocratis.

Fig. 129 represents the fascia nodosa or knotted bandage. The middle of a strip of bandage is laid, for example, on the left temple, and one end of the strip is carried over the crown, the other under the chin to the right temple, and at this point the two ends are crossed, the one which came from under the chin passing around the forehead, the other around the occipital region, and the two ends are then knotted together. The principle of this knotted bandage can be used with some variations for almost any desired portion of the body. Its chief use is for exerting pressure on some particular spot, which can be increased by inserting beneath the bandage a pad of cotton or gauze, etc.

It is also used in the inguinal region (Fig. 157), as a temporary substitute for a hernia truss.

Mitra Hippocratis.—The mitra Hippocratis (Fig. 130) is made with a double roller, or, what is simpler, with an ordinary roller bandage. When the double roller is employed its centre is applied in the middle of the forehead, one roller being carried horizontally around the head towards the right, the other towards the left, and at the occiput the two rollers are crossed in the manner of the fascia nodosa; then an assistant carries one roller over the crown to the forehead, while the operator, with the second roller, takes a circular turn horizontally around the head and crosses the roller, which has been carried over the crown, upon the forehead. This is continued, one roller being carried from the forehead to the occiput and then back again to the forehead, first on the right side and then on the left of the original median strip carried sagittally over the crown, each circular turn of the other roller securing the strips passing over the crown. The entire skull is thus covered with strips of bandage running forwards and back in a sagittal direction. Finally, the ends of both rollers are carried circularly around the head and fastened in place with a safety-pin. The mitra Hippocratis is only occasionally applied with a double roller, but it is well to understand the principle of it in treating wounds of the head antiseptically (see page 152, Fig. 118). A mull or wet gauze bandage may be applied to the skull partly with circular turns and partly with turns passing back and forth in the sagittal direction over the top of the head.

Capistrum Duplex.—The capistrum duplex is not very often used now, but it was at one time in great repute for treating fractures of the lower jaw, as was also the capistrum simplex. The funda maxillæ (Fig. 148) has the same effect as the capistrum simplex and duplex, and is, furthermore, much better and simpler. Some of the turns made in the capistrum duplex are used for applying antiseptic dressings to the head and neck, and hence it should be spoken of here. The description of the old-fashioned capistrum simplex will be omitted. The capistrum duplex is begun with the end of the roller on the vertex, then it passes down in front of the left ear, under the chin, and up in front of the right ear to the vertex again; then from this point it passes around the occiput to the right side of the neck, under the chin, and up in front of the left ear, covering the first turn in great part, back to the vertex again; then around the occiput to the left side of the neck, beneath the chin, and up in front of the right ear to the vertex. In this way three turns of the bandage are made in

Fig. 131.
Capistrum duplex.

front of each ear, and then it is carried from the neck in front of the chin and the lower part of the under lip, and is finally terminated by a circular turn around the forehead and occiput. The circular turn around the front of the chin can be made between the second and third turns taken in front of the ear. In applying an antiseptic dressing the neck should also be included in the bandage.

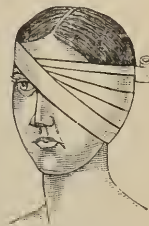


Fig. 132. Monoculus.

Monoculus and Binoculus.—Fig. 132 represents the method of applying the monoculus, which begins with a circular turn about the head, starting from the temporal region. The rest can be understood from Fig. 132. The so-called binoculus, or bandage over both eyes, is performed by first covering one eye with a circular turn of the bandage and then carrying the bandage with obliquely descending turns over the other eye.

Application of a Bandage to Neck and Thorax.—The application of bandages to the neck is accomplished by making circular turns, to which, in the case of large wounds, are added cross turns under the axilla and over the shoulder (see page 152, Fig. 119). Bandages are applied to the thorax by circular turns, with or without reverses. To keep the bandage from becoming displaced, every other turn can be carried from the back over the shoulder and secured with safety-pins at the points of meeting with the horizontal turns; or the circular turns may be made to ascend from below upwards on the thorax, and finished by oblique turns about the shoulder and axilla like a spica humeri (Fig. 138, *a* and *b*). For bandaging a wound, after applying a thick cushion of dressings, we employ starch bandages, which, after drying, fit closely and do not become easily displaced. Elastic bandages are also to be recommended for the trunk, as they retain their position very well.

Fig. 133.—Suspensorium mammæ duplex and small outer bandage for the mamma.

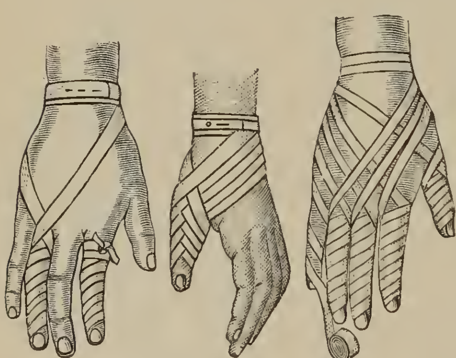
Bandaging of the Mamma. *Suspensorium Mammæ Simplex* (Fig. 133).—The bandage for the right mamma is begun by a circular turn about the lowermost portion of the thorax. The bandage is then carried obliquely so as to envelop the lower part of the gland, over the opposite shoulder, then across the axilla, over the shoulder and across the back, again to the right breast at its upper part, and then once more over the shoulder, etc. The upper and lower portion of the gland is crossed alternately, and then its middle

part, and finally the bandaging is completed by a circular turn around the lowermost portion of the thorax covering the preliminary turns (Fig. 133). The suspensorium mammæ duplex and a light supporting bandage for both breasts can be applied very simply by using the method illustrated in Fig. 133 on both sides.

Antiseptic Retention Dressing after Amputation of the Breast and cleaning out the Axilla.—After amputation of the breast, accompanied by cleaning the carcinomatous lymphatic glands out of the axilla, I first put on a dressing of several layers of sterilised gauze placed in direct contact with the wound, then over this I apply absorbent cotton or pads of jute, covering in the shoulders and entire thorax. These materials are then bound on by a sterilised mull bandage encompassing the thorax, neck, and shoulders, the edges of the dressings, particularly in the axilla, neck, and at the lower border of the breast, being very carefully filled in with absorbent cotton; then the arm on the side which has been operated upon is placed in contact with the thorax and also covered with sterilised absorbent cotton. After this the arm is immobilised by a disinfected mull and finally a gauze bandage encircling the thorax, neck, and shoulder (Fig. 134).

Fig. 134.—Aseptic dressing for use after an amputatio mammæ with cleaning out of the left axilla.

Application of Bandages to the Upper Extremity. — The methods of applying bandages to the fingers are illustrated in Fig. 135, *a*, *b*, *c*. They are begun with a circular turn around the wrist, and then carried across the dorsum of the hand to any particular finger, and, after encircling it, brought back again to the back of the wrist (Fig. 135, *a*). A finger can be bandaged, as illustrated for the



a *b* *c*

Fig. 135.—Application of bandages to the fingers.

little finger in Fig. 135, *c*, by making oblique spiral turns down to its tip, and then covering in the finger by oblique or circular turns from tip to base. The finger bandage can also be carried in the reverse direction, beginning on the finger and terminating at the wrist. Moreover, the thumb may be bandaged in the way pictured in Fig. 135, *b*; beginning with a circular turn around the wrist, the bandage is carried to the tip of the thumb, and around this, over the back of the hand, and so on, with oblique turns till the base of the thumb is reached. If it is desired to bandage the tip of the finger, the roller is carried along the back or palmar surface of the finger over its tip and back on the other side opposite the starting-point, where it is retained while a circular turn is made around the base of the finger, over the ends of the loop, securing it in its position. A bandage is applied to the whole hand according to the rules for the spica manus (Fig. 136). The bandage is started at the wrist by a circular turn, and then oblique or figure-of-eight turns are taken by the roller, gradually proceeding downwards till the finger ends are reached. It is concluded with a circular turn about the wrist.

Fig. 136. Spica manus.

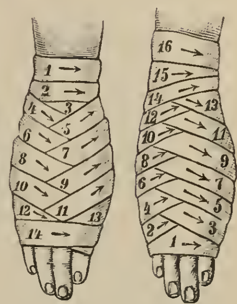


Fig. 137.—Bandage for the hand.

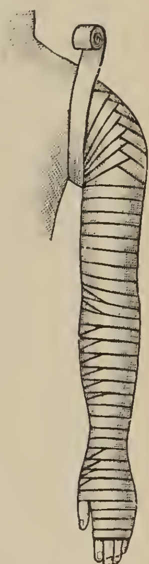


Fig. 139.—Bandage for the entire upper extremity.

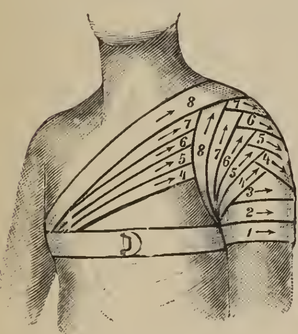
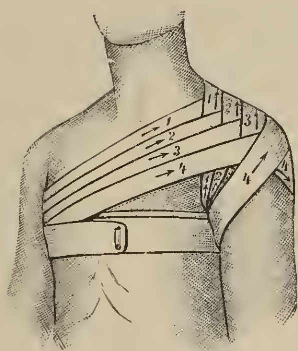


Fig. 138.—*a*, Spica humeri ascendens.



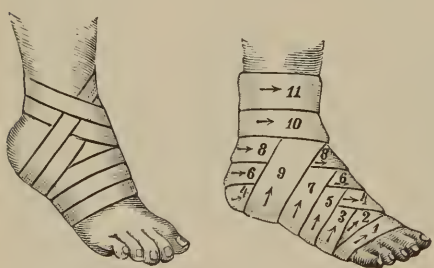
b, Spica humeri descendens.

Another way of bandaging the hand is represented in Fig. 137, *a* and *b*. It is begun with a circular turn around the wrist (Fig. 137, *a*)

or around the ends of the fingers, and proceeds up or down with figure-of-eight or oblique turns, half of the width of each upper turn overlapping a corresponding amount of the next lower turn, and finally terminating with a circular turn around the finger tips or the wrist. If it is desired to include the finger tips, as, for instance, in an antiseptic protective dressing, the end of the bandage is secured while the roller is carried over and around the ends of the fingers and back on the opposite side in the form of a loop, and the extremities of the loop are then fastened in place by a circular turn.

Application of a Bandage to the Shoulder.—The shoulder is bandaged by using the spica humeri ascendens (Fig. 138, *a*) or descendens (Fig. 138, *b*). The spica humeri ascendens (Fig. 138, *a*) begins with a circular turn around the upper end of the arm, the bandage being then carried over the lower end of the shoulder from within outward, then over the back to the opposite axilla and back again across the breast over the shoulder through the axilla, and finally terminated by a circular turn around the thorax. The spica humeri descendens (Fig. 138, *b*) is applied in the reverse direction—i. e., it is begun with a couple of circular turns about the thorax, and finished with descending oblique or cross turns over the shoulder, terminating on the arm lower down, or with a circular turn about the thorax again. Fig. 139 represents the method of applying a bandage to envelop the whole arm. The turns of the spica humeri around the thorax are omitted in the illustration in order to economise space, but the rest of the figure illustrates the bandage for the entire upper extremity.

Application of Bandages to the Lower Extremity.—The bandage for the lower extremity is begun by enclosing the foot (Fig. 140, *a* and *b*) by a circular turn made back of the toes, as illustrated in Fig. 140, *a*; then two or three slightly oblique turns are taken, with or without the reverse (Fig. 127), and at about the fourth turn of the bandage the latter is carried obliquely over the anterior aspect of the ankle-joint toward the internal malleolus, and from here over the heel and around the outer malleolus again to the inner side of the foot; thence across the sole, making two or three stirrup turns, and then ascending the leg with circular turns, followed by oblique turns and the reverse (Fig. 127). If the heel is to be included (Fig. 140, *b*), the bandage is begun

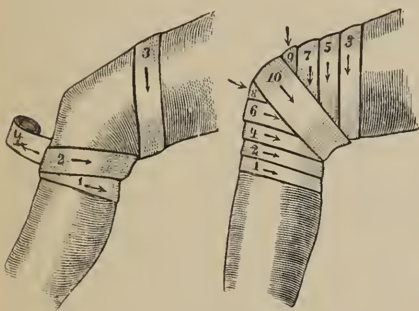


a *b*

Fig. 140.—Application of bandages to the foot.

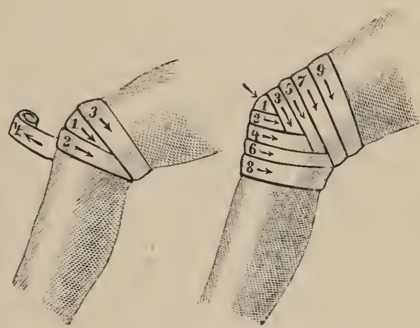
as in Fig. 140, *a*; but after taking two or three turns, it is carried across the dorsum of the foot to the heel, around the latter, over the dorsum to the inner side of the foot, thence across the sole to the outer side of the foot, again over the dorsum to the heel, each preceding turn being covered by half the width of the following turn, and so on till above the ankle, when two circular turns are made, and then these are succeeded by oblique turns with reverses ascending the leg.

For applying a bandage to the region of the knee-joint the testudo inversa (Fig. 141, *a* and *b*) or reversa (Fig. 142, *a* and *b*) is used. In



a *b*

Fig. 141.—Testudo inversa genus.



a *b*

Fig. 142.—Testudo reversa genus.

the testudo inversa (Fig. 141), after several circular turns are made around the leg, an oblique turn is carried across the popliteal space toward the thigh, passing around the latter back across the popliteal space to the leg and so on gradually covering in first the lower, then the upper part of the anterior aspect of the knee, the last turn crossing the centre of the anterior aspect of the knee transversely (Fig. 141, *b*). The testudo reversa is begun with a circular turn around the middle of the knee, and the remaining turns are made obliquely, first above and then below the original circular turn.

The testudo bandage is also employed for the elbow.

When it is desired to wrap the entire lower extremity in a bandage, the region of the knee may be covered simply by circular turns (Fig. 145). The hip, in the same way as the shoulder, may be bandaged by a spica coxæ ascendens (Fig. 143) or descendens (Fig. 144). The spica coxæ ascendens is begun with a circular turn around the upper part of the thigh, and then, in the case of the left hip, the bandage is carried across the gluteal and sacral region towards the opposite anterior superior spine of the ilium, thence over the lower part of the abdomen and inguinal region back to the thigh. For the right thigh, the bandage is carried over the groin and abdomen to the anterior superior spine,

14

thence across the sacral and gluteal regions back to the thigh. Each succeeding turn ascends a little higher on the thigh, and the bandage is finally completed by a circular turn around the abdomen. The spica coxæ descendens (Fig. 144) is begun where the ascendens terminates, by circular

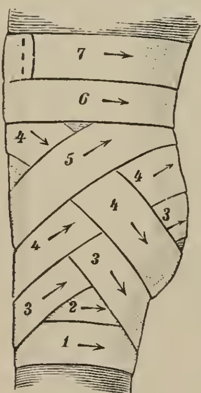


Fig. 143.—Spica coxæ ascendens.

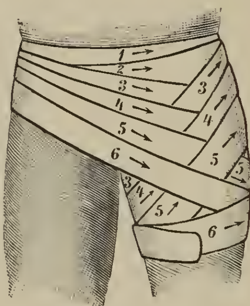


Fig. 144.—Spica coxæ descendens.

Fig. 145.—Bandage for the entire lower extremity.

turns around the abdomen, and is made to descend by oblique turns in a manner the reverse of the spica ascendens, and finally to come down the thigh by circular and oblique turns made with reverses. The method of bandaging the entire lower extremity will be understood from the previous remarks (Fig. 145).

§ 51. **Application of suitably shaped Pieces of Cloth in place of Bandages.**—Properly shaped pieces of cloth as substitutes for bandages are

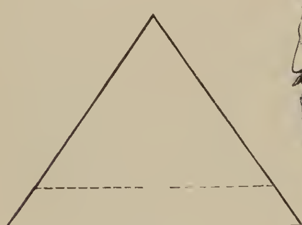


Fig. 146.—Double piece of cloth; bandage to support the jaw.

Fig. 147.—Handkerchief or impromptu cloth bandage for the jaw.

Fig. 148. Funda maxillæ.

not suitable for dressing wounds antiseptically, but under other circumstances—viz., for applying a light protective dressing, or for the after-treatment of a wound, or in an emergency—they do very well,

and possess the advantage that the material for making them can always be obtained in every household. These bandage substitutes are made of triangular or quadrilateral-shaped pieces of cloth. One of the most useful of these bandage substitutes is the sling bandage. The base or longest of the three sides of a triangular piece of cloth is cut in the manner indicated by the dotted lines in Fig. 146, thus making a five-tailed piece of cloth, which is excellent as a bandage for the inferior maxilla (Fig. 148). Another very good bandage substitute may be made by splitting the smaller sides of a long rectangular piece of cloth and applying it as a bandage for the head in the manner indicated in Fig. 147, *a* and *b*.

These pieces of cloth used as bandage substitutes may either be folded up in the shape of a cravat and made to encircle any part of the body, or they may be used as simple unfolded pieces of cloth. The folded strips are applied like any ordinary roller bandage. For the sake of brevity I shall confine myself to the following short description of the different methods of using these substitutes for roller bandages.

As regards the head, a triangular piece of cloth folded into the shape of a cravat is an excellent substitute for the monoculus in bandaging the eye, and for making a horizontal bandage on the forehead like the fascia nodosa (Fig. 129). A very useful bandage as a temporary dressing for a fracture of the upper or lower jaw is the funda maxillæ (Fig. 148), which is made from the five-tailed sling bandage represented in Fig. 146. The three-cornered piece is folded up like a cravat, the middle of which is placed under the chin of the patient, and the two ends are knotted together upon the top of the head. The point of meeting of the other two tails is held in front of the chin, and the ends of these tails carried around the back of the neck, where they are crossed and brought forward and knotted together on the forehead. Mention should also be made of the capitium parvum, magnum, and quadrangulare.

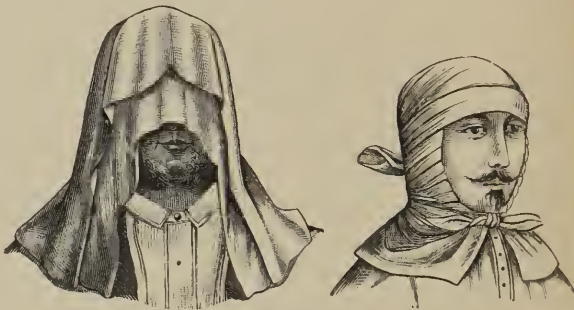
Fig. 149.
Capitium parvum.

The Small Head-dress (*Capitium parvum*, Fig. 149).—An ordinary triangular piece of cloth is laid over the head, with the centre of its longest side at the root of the nose, and its apex or angle opposite the longest side hanging down the neck. The lateral tails of the triangle are carried around the neck back to the forehead, where they are tied together. The tail hanging down the neck is turned back over the top of the head and secured with a safety-pin.

The Large Head-dress (*Capitium magnum*, Fig. 150).—The triangu-

lar sling bandage is cut in the manner represented in Fig. 146 and laid on the scalp, with the centre of its longest side at the root of the nose.

Fig. 150.—Large handkerchief bandage for the head.



a b

Fig. 151.—Capitium quadrangulare.

The two anterior tails hanging down on each side of the face are passed around the neck, as in the capitium parvum, and brought forwards and knotted together on the forehead. The other two tails are tied under the chin, and the apex of the triangular piece of cloth is finally brought forwards, as in the capitium parvum, from beneath the tails, crossed behind the neck, and secured in front by a safety-pin.

The Four-tailed Head-dress (*Capitium quadrangulare*, Fig. 151, *a*).—A quadrilateral piece of cloth is so folded over the top of the head that its under border overlaps the upper by about a handbreadth (Fig. 151, *a*). The two upper—or, rather, posterior—angles are knotted together under the chin, while the other two corners are drawn somewhat forwards and upwards. Then the projecting lower edge of the under portion of the cloth is turned up and back, and the two anterior corners are carried around behind the neck and tied, thus forming the bandage represented in Fig. 151, *b*.

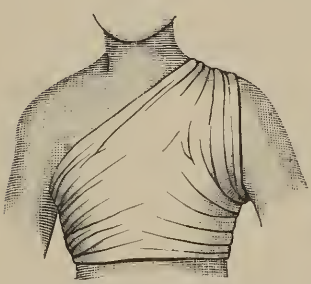


Fig. 152.—Handkerchief bandage for the breast.

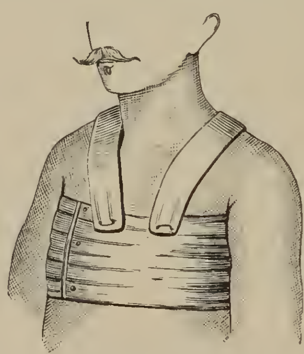


Fig. 153.—Handkerchief bandage for the breast.

An ordinary three-cornered piece of cloth can be applied to the thorax in the manner illustrated in Fig. 152. The longest side of the triangle is placed around the lower portion of the thorax, while the

apex or opposite angle of the triangle is carried over either the right or left shoulder and tied to the other two tails or angles of the triangle behind.

In suitable cases a bandage may be applied as in Fig. 153—i. e., a folded piece of cloth is placed around the thorax and prevented from becoming displaced by a couple of retention straps carried over the shoulders and having their junctions with the breast-piece secured by safety-pins. The female mamma can be supported by an ordinary triangular piece of cloth, or one made double, as shown in Fig. 146. The sling is applied with the centre of the base of the triangle beneath the breast which it is desired to support. Then the lower tails or corners at each side of this point are carried around the thorax, while the other three tails are conducted across the axilla and over both shoulders to the back, where they are tied together.

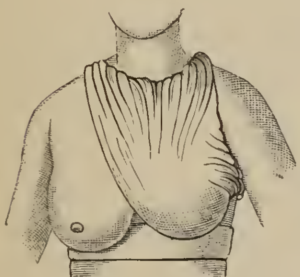
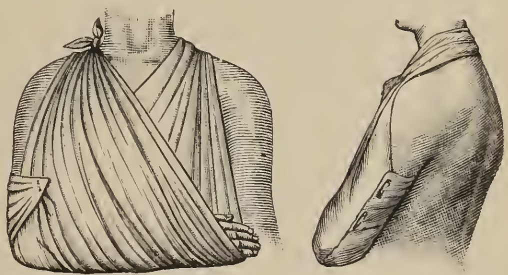


Fig. 154.—Handkerchief bandage for supporting the mamma.



a *b*

Fig. 155.—Mitella.

The triangular piece of cloth is very frequently used for making the so-called mitella, or arm support (Fig. 155). The following is the method for applying the mitella: The three-cornered piece of cloth is grasped at each extremity of one of the shorter sides and placed between the thorax and the arm bent at right angles, with one angle of the triangular cloth projecting around back of the elbow. The upper end of the longest side is then carried over the opposite shoulder and tied to the other end of the longest side behind the neck. The third corner or angle of the triangular cloth is carried around the back of the elbow to the front and secured in this place by a safety-pin (Fig. 155, *a*). Instead of bringing this third angle around in front of the elbow, it can be turned in, and then the two edges of the sling can be pinned behind the arm, as represented in Fig. 155, *b*. Moreover, it is a very good plan not to tie the ends of the sling around the neck, as the knot causes discomfort, but to bring the extremities to the front again, and either sew or pin them in that position.

A four-tailed or four-cornered piece of cloth can be used for a sling, like the mitella, but the manner of its application is more complicated, without being any better.


Fig. 156.—Handkerchief bandage for the shoulder or axilla.

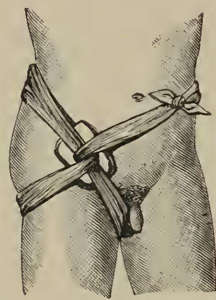


Fig. 157.—Knotted bandage about the inguinal region.

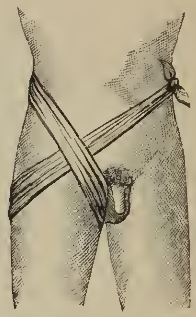


Fig. 158.—Handkerchief bandage about the inguinal region.

Strips of bandage can be used instead of the mitella. They are fastened to the coat or tied around the neck. An ordinary sling can be made for the arm, with a couple of suspensory strips attached to encircle the neck, or the forearm can be bent at right angles and the hand inserted in the waistcoat or partially buttoned coat.

In Figs. 156 to 160 are represented the methods for applying pieces of folded cloth around the axilla or the shoulder, about the inguinal region, the hand, and foot, and they need no further explanation. In Fig. 157 the principle of the fascia nodosa is used (Fig. 129)—i. e., the ends of the bandage are twisted about each other for exerting pressure upon some particular spot. By means of a pad of cotton, lead, rubber, or other material, the pressure can be increased.


Fig. 159.—Handkerchief bandage for the hand.


Fig. 160.—Handkerchief bandage for the foot.


Fig. 161.—Handkerchief bandage for the hand.


Fig. 162.—Handkerchief bandage for the foot.

In Figs. 159 and 160 are represented the methods of applying a bandage substitute to the hand and foot. The hand is wrapped in a three-cornered piece of cloth in the following manner (Fig. 161): The centre of the base of the triangle is placed at the wrist, while the angle opposite the base projects a little beyond the tips of the fingers. This projecting angle is then turned back over the fingers and dorsum of the hand to the wrist, the lateral angles are given a turn around the wrist and made to cross each other on the dorsum of the hand, then brought back to the wrist and tied. The same idea is carried out on the foot, but instead of knotting the ends around the leg, they can be carried back from the leg and crossed over the dorsum of the foot, and finally tied after making a circular turn around the foot (Fig. 162).

CHAPTER IV.

THE SICK-BED OF THE PATIENT.—IMMOBILISATION APPLIANCES AND DRESSINGS.

The sick-bed of the patient.—The bed.—Adjustable beds.—Bed fittings: Air-cushions; water-cushions.—Supports.—Wire cradles.—Appliances for lifting patients.—Appliances for the sick-bed: Cushions; straw splints.—Planum inclinatum simplex and duplex.—Petit's leg splint.—Suspension.—Wire gutters and baskets.—Splints. —Materials for making splints (wood splints, paste splints, metal splints, glass splints, plaster splints, extension splints, articulated splints).—Complicated appliances for the sick-bed.

§ 52. **The Sick-bed of the Patient.**—The greatest care must be exercised as regards the sick-bed of the surgical patient. The bed should be so arranged that the injured portion is easily accessible to the physician. In general, it is best to place the head of the bed towards the window, to prevent the patient from being blinded by the light. It should be as elastic as possible, and a spring or horse-hair mattress is far preferable to a feather bed. If the patient must be confined to bed for a long time, it is a very good plan to have a bedstead with contrivances for changing its shape, so that he can readily be brought into the horizontal or sitting position. A bedstead which the patient can adjust to suit himself with very little effort is particularly good. A water-tight rubber protective should be placed over the mattress to prevent it from getting wet. "Christia," a comparatively cheap, durable, and sterilisable preparation, has been recommended by Evens and Pistor, of Cassel, as a substitute for the ordinary water-tight substances hitherto used (rubber, oiled silk, gutta-percha, muslin, etc.). The greatest care must be used to keep the bed-linen perfectly clean, so that the dressings shall remain antiseptic. If the patient must lie for a long time upon his back, the sacral region particularly should be protected from all injurious pressure by means of elastic cushions. For this purpose we use ring-shaped air-cushions, or, what is still better, large water-cushions filled with warm water.

By means of a swinging crane placed over the head of the bed, or a sling attached to the foot of the bed, the patient is enabled to raise himself. By means of hoops joined together, or cradles (Fig. 163),

the bed-clothes can be elevated from the diseased portion of the body upon which their pressure may be uncomfortable, or sometimes even painful.

For lifting the patient or some portion of his body with as little disturbance as possible, we make use, when necessary, of special appliances called lifts. In the majority of instances they are not needed for changing the dressings or bed-clothes, or for enabling the patient to empty his bowels, and a nurse can render all the assistance required; but under many conditions—for example, when the dressings on a compound fracture have to be renewed, and the part must be held lifted up from the bedding for some time while it is being done—we employ windlasses, pulleys, belts, fenestrated scaffolds, etc. The portable fenestrated bed-lift, which is extensible and permits of defecation in the recumbent position, invented by Hamilton and Volkmann (Fig. 164), and Hase's apparatus (Illustr. Monatschrift d. ärzt. Polytech., Heft 6, 1883), are very useful contrivances. Volkmann's bed-lift is placed on the bed over the mattress and can be raised by two attendants, while the supports at each extremity can be automatically adjusted so that the apparatus can be retained at any desired elevation. Hase's apparatus consists of two steel rods with cross-bars in the region of the shoulders and pelvis, and three straps for raising the head and legs; from each one of these five parts a rope is carried over a roller on a crane projecting over the bed, and the patient is raised into an elevated position by turning a windlass. For elevating any single portion of the body, such as an extremity, the ordinary suspension apparatus will be found sufficient (Fig. 168). For enabling the patient to raise the upper portion of his body, cranes can be devised with two ropes and rings for him to grasp, or straps can be attached to the ceil-

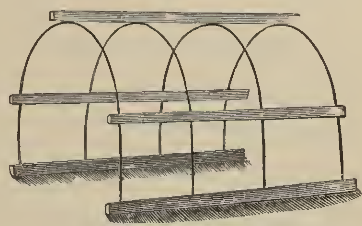


Fig. 163.—Wire cradle for the limbs.

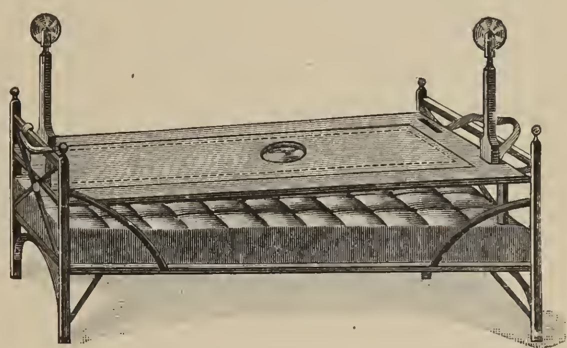


Fig. 164.—Elevated frame for fractures of the vertebræ and pelvis (Hamilton, Volkmann).

ing or to the foot of the bed. The pelvis of the patient may be lifted by a trestle on which is stretched a broad leather belt provided with a fenestrum for permitting evacuation of the bowels. But if it is impracticable to disturb the position of the patient at all, an opening can be provided in the mattress and bottom of the bed for enabling him to empty his bowels, or an arrangement can be made by which the mattress may be drawn from under him. The adjustable bed of Hamilton and Volkmann is exceedingly well adapted for this purpose.

§ 53. **Sick-bed Appliances—Splints, Cushions, etc.**—There are numerous apparatus and contrivances for obtaining the necessary and secure position of a patient who is confined to bed, or of the particular part of the patient which has been operated upon.

1. **Cushions.**—The most useful cushions for retaining a diseased part in any required secure position are made of chaff, chopped straw, sawdust, or sand. The cushions should be only partially filled, so that the contents may be shifted and the cushion given any desired shape for fitting the injured extremity and holding it securely. Sand bags or cushions are excellent on account of their weight, and the long, sausage-shaped bags are the best, as they can be placed along the whole length of each side of an extremity, especially the leg. Chaff cushions are also very good, as their contents can be collected at each end of the bag, which may then be wrapped around an extremity and secured by a bandage, cloth, etc. The same effect was obtained by the old-fashioned straw splint (Fig. 165), which can be made very simply by wrapping the two ends of a good-sized strip of cloth around bundles of straw or some similar material; the extremity is placed between two bundles, where it can be secured with a bandage.

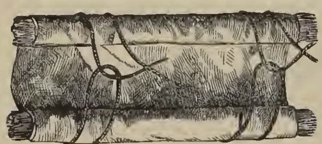


FIG. 165.—Straw splint for temporary use.

Tightly stuffed cushions of horse-hair or seaweed, the shape of which cannot be altered, are also used. In this class are Stromeyer's triangular axillary cushion with its rounded corners, and Middledorff's wedge cushion for fracture of the humerus. Large, wedge-shaped pads have been invented for the lower extremity also, having two plane surfaces inclined at an angle to each other.

2. **The Single and Double Inclined Plane.**—If it is desirable to elevate the peripheral end of an extremity either for inflammatory swelling, simple congestion, or for some injury or after an operation, it can be accomplished very readily by placing beneath the extremity chaff cushions arranged so as to form a simple inclined plane. The same re-

sult can be attained by placing under the leg an ordinary board with its distal end raised, and particularly by using Petit's box splint (Fig. 167). The double inclined plane is used chiefly for the lower extremity. A large, wedge-shaped cushion will answer the purpose, or a couple of boards joined by a hinge and fastened with strings so as to maintain any desired angle. Esmarch's planum inclinatum duplex fitted with lateral retention pegs is exceedingly useful (Fig. 166).

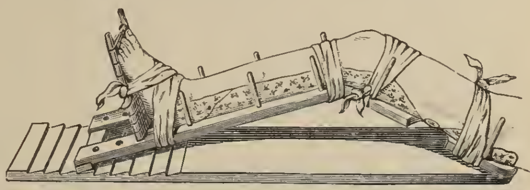


Fig. 166.—Planum inclinatum duplex.

3. **Splints.**—Leg splints are chiefly employed for fractures below the knee, and they may be used with advantage in all injuries of the leg. Petit's splint is a thoroughly good one (Fig. 167). Heister introduced it in Germany, and consequently it has been called by the latter's name. By means of the wooden props attached to its bottom the splint can be raised or lowered, producing a greater or less amount of flexion at the knee, as the board under the thigh moves with the splint, to which it is attached by a hinge joint. This splint can be made into either a planum inclinatum simplex or duplex. The side- and foot-pieces can also be turned down, rendering frequent inspection of the extremity possible. The position of the extremity is represented in Fig. 167, with the pads which surround it. A long chaff cushion is laid on each side of the leg, and a greater or less amount of cotton or jute is stuffed into the inequalities to prevent any displacement of the fragments in the broken leg. Several turns of a bandage, or folded strips of cloth, are taken around the foot and foot-piece and around the leg and body of the splint to secure the limb in position.

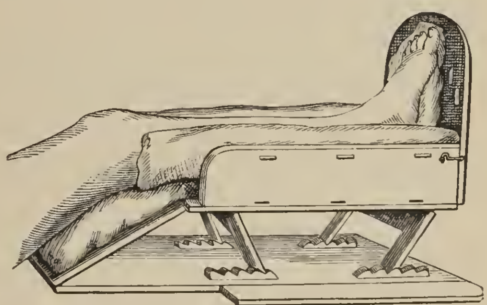


Fig. 167.—Petit's box-splint for the leg.

4. **Suspension.**—All the old-fashioned suspension appliances for holding the extremity in proper position are at present entirely superfluous, as we now combine all the various retention and extension dressings with suspension. Retention dressings, particularly plaster bandages, will be again referred to later on. As will be seen, we now use, in

combination with suspension, retention dressings, which harden after their application, especially plaster-of-Paris bandages, with or without inserting splints or telegraph wire (Figs. 168, 169, 181, 182, 186, 196, 198, 199, 207, 208, 209). Amongst the various kinds of suspension splints in use those chiefly worthy of mention are Volkmann's (Fig. 177), Esmarch's wood or telegraph wire splint for the upper and lower extremities (Figs. 169, 182), Smith's anterior wire splint (Fig. 186), Beely's gypsum-hemp splint (Fig. 200), Volkmann's wooden dorsal splint (Fig. 181), and Esmarch's stirrup splint for the leg and foot, which consists of two splints, one for the sole of the foot, the other for the leg, the two being joined by a dorsal arch or bow. The special splints adapted to curvature of the spine will be described in the text-book on Special Surgery. Rauchfuss's suspension appliance is represented in Fig. 218.

Fig. 168.—The author's suspension apparatus.

The simplest way of suspending the lower extremity is illustrated in Fig. 196, where the limb is encased in a fenestrated plaster splint and hung from a wood or iron frame by a couple of strips of bandage. The point of support can also be arranged in the form of a gallows having a horizontal stick of wood attached at right angles to an upright (Figs. 207, 208). I use an adjustable iron frame with rollers, as in Fig. 168. The cross-bar can be raised or lowered to any convenient height by means of the handle A. The rope for exerting the traction with the weight G runs over wheels, which can be moved to one side or the other and readily retained at any point by the notches in the cross-bar. Iron frames which can be fastened to the bed are very useful.

5. **Wire Splints.** *Wire Gutters, Stockings, and Cases.*—Wire gutter splints (Figs. 170, 172) are as simple as they are comfortable, and have supplanted to a large extent the contrivances just described. Wire gutters are usually made of wide-meshed wire gauze, padded with a thin layer of horse-hair or small cushions of cotton, jute, etc. They are

straight, or bent at an angle, and of various lengths and sizes. As they are flexible they can be made to fit the limb more or less accurately by means of straps. Roser's contrivance is very useful. It consists of a

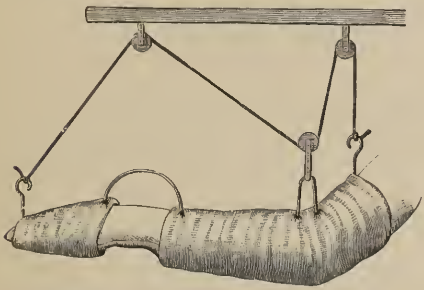


Fig. 169.—Suspended upper extremity; interrupted plaster dressing with splints and telegraph wire.

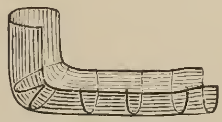


Fig. 170.—Wire gutter for the upper extremity.

Fig. 171.—Wire gutter for the lower extremity.

wire gutter for the entire lower extremity, and is made in two or three different parts, which can be telescoped together to any desired extent and fixed in the proper position with strings. For immobilising both lower extremities, together with the pelvis, for example, in fractures of the latter, Bonnet's wire stockings are widely used (Fig. 172). Bonnet has also invented an excellent wire frame or case for enclosing the whole body in fractures of the vertebræ.

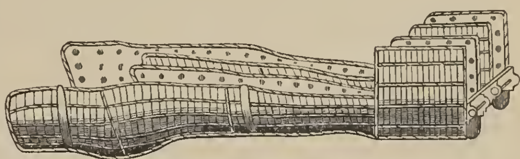


Fig. 172.—Bonnet's wire stocking for both lower extremities and the pelvis.

6. **Splints and Splint Bandages.**—Splints are generally employed in the treatment of fractures and in making dressings which harden after their application, as well as ordinary antiseptic dressings.

Splints are made in an immense variety of shapes, either resembling more or less deep gutters, or only slightly concave or entirely flat; they may be straight, or bent at a right, acute, or obtuse angle. The particular kind of splint required for this or that portion of the body will be dealt with in the Special Surgery, and only a general review will be given here. Splints are made of wood pulp, metal, silica, felt, plaster, etc.

Wooden Splints.—The stiff, unyielding wooden splints are usually made from the coarse heart wood of the tree; they are flat or slightly concave, or fashioned to fit the contour of a particular portion of the body, and they may be straight or bent at an angle. Fenestræ are usually cut in them to correspond to any projecting portions of the body,

such as the internal condyle of the humerus at the elbow, or the malleoli at the ankle, and thus the skin over these points is preserved from an

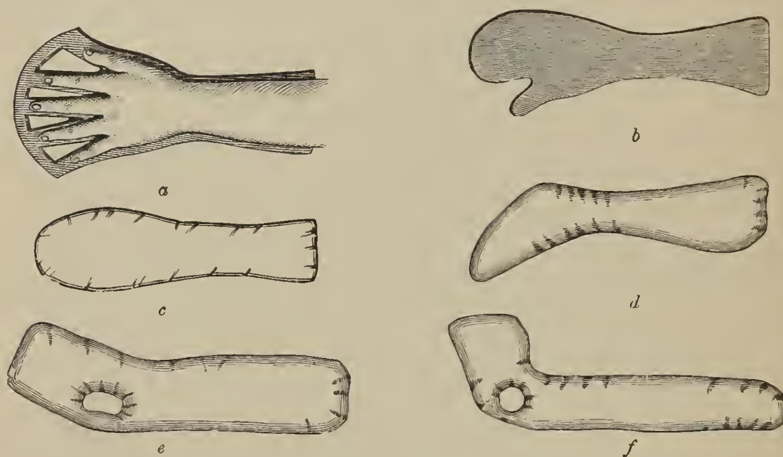


Fig. 173.—Splints for the arm and hand.

undue amount of pressure, which might cause it to become gangrenous. In Fig. 173 are represented various kinds of splints for the upper extremity; they are straight, or bent at an acute or obtuse angle, and made

Fig. 174.—Esmarch's splint for the arm in case of resection of the elbow.

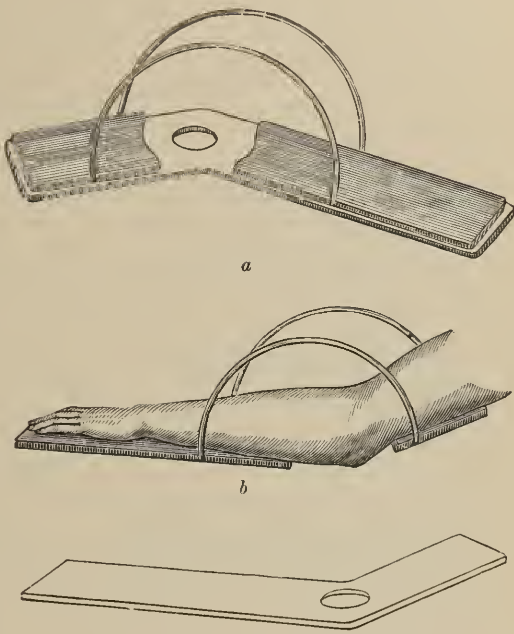
Fig. 175.—Volkmann's supination splint.

of wood or papier-maché. The splints (*c* to *f*) are padded with cotton, jute, or tow, and then covered with rubber tissue, the ends of which are stuck to the back of the splint with chloroform. These splints are used almost exclusively for inflammation, injuries, and fractures of the fingers, hand, and forearm. The splint *d* is somewhat modified from Nélaton's pistol splint for fracture of the radius.

Wooden arm splints for the entire upper extremity can be made like the models represented in Fig. 173, *e* or *f*. Esmarch's arm splints (Fig. 174) are also very useful, for example, after resection of the elbow-joint; Volkmann's supination splint is likewise good, and enables the arm to be immobilised in a position between pronation and supination (Fig. 175).

Esmarch's double splint (Fig. 176) is exceedingly good for a resected

elbow-joint. It consists of two parts upon which the arm rests, the upper portion being joined to the lower by a steel bow (Fig. 176, *b*). If it is desirable to place the forearm and hand in a vertical position, in cases of acute inflammation, in order to lessen the congestion, Volkmann's suspension splint is very useful (Fig. 177); the ring at the extremity of the splint is employed for suspending it in the vertical position; but an arrangement of cushions and bandages will ordinarily be found sufficient for securing the forearm in position.


a

b

c

Fig. 176.—Esmarch's double splint for resections of the elbow.

The two excellent splints of Esmarch and Lister for resection of the wrist are represented in Fig. 178, *a*, *b*, and Fig. 179. Esmarch's bow splint is easily made from a piece of wood or sheet iron.

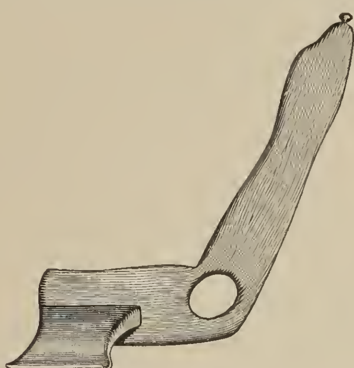


Fig. 177.—Volkmann's suspension splint.

Amongst the great number of wooden splints for the lower extremity, mention should be made particularly of Watson's splint (Fig. 180) for the posterior surface of the leg, with a notch for the heel, and of Bell's splint for the thigh or leg, made of two strips of wood buckled together by a strap. Volkmann's wooden dorsal splint is another good one (Fig. 181).

Esmarch's wooden splint for resection of the ankle-joint is represented in Fig. 182; it is applied to the posterior surface of the leg,

which is then wrapped in gypsum bandages and suspended from hooks made of telegraph wire.

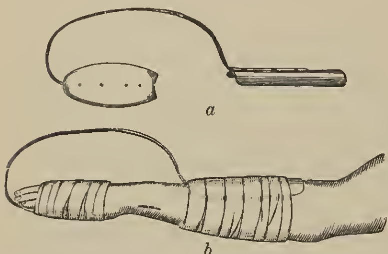


Fig. 178.—Esmarch's interrupted splint for resections of the wrist.

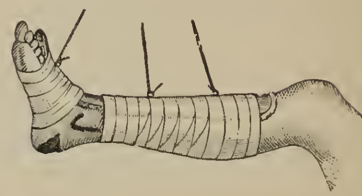


Fig. 181.—Volkmann's dorsal splint (for suspension).

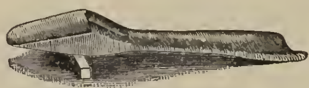


Fig. 179.—Lister's splint for resections of the wrist.

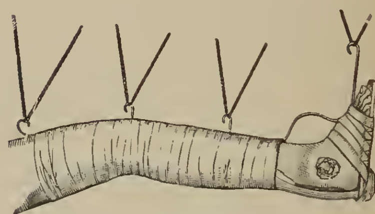


Fig. 182.—Esmarch's wooden splint for resections of the ankle.

Fig. 180.—Watson's splint for the lower extremity.

Pliable Wooden Splints.—In addition to these stiff wooden splints there have been recommended splints made of wood which is capable of bending, but they have not been received with as much favour as they deserve. They are always well suited for making an impromptu dressing, especially in transporting patients to the hospital. Even in ancient times, according to the assertion of E. Fischer, splints were manufactured from wood which could be bent into any desired shape. For this purpose there were used the stem of the Spanish broom, strips of wood cut very thin, pieces of veneering, green twigs, palmetto leaves, and the bark of trees. According to the same authority the Turks use moulded wooden splints made of the fibrous portions of palmetto leaves sewed to thin leather, thus obtaining a material which can be applied to an injured limb either circularly or in the form of a gutter. Martini and Gooch glue narrow, thin strips of wood taken from the linden tree close together upon soft leather, and

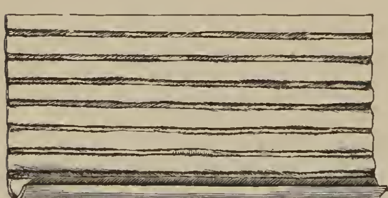


Fig. 183.—Esmarch's materials for making splints.

in this way a splint can be made which is an excellent temporary dressing for a fracture, particularly of the lower extremity. Esmarch's splint material, which can be cut into any required size, is very similar to this (Fig. 183). It consists of strips of wood three centimetres wide and one and a half centimetre thick, which are glued between two layers of cotton cloth. Herzenstein advises that splints be made after the fashion of the ordinary trellis work used for supporting vines. Reeds, willow withes, and straw made into mats have also been recommended as splints. Thin, pliable strips of wood about three to four centimetres wide make a very good material for splints when combined with plaster bandages, and are also very useful for immobilising a joint after an antiseptic dressing has been applied.

Wood Dressings.—Waltuch recommends wood dressings made of shavings, 4·5 centimetres wide and 0·5 to 1 millimetre thick, and any desired length, which are prepared by planing pine planks in a particular way. The wood shavings roll up spontaneously like a bandage, are more easily handled than thin board splints, and much cheaper than the latter. This wood dressing, consisting of shavings bound together with glue, is suitable for corsets, for encasing a limb, etc. (Wien. klin. Wochensch., 1888, No. 10.)

Papier-maché Splints.—Splints made of stout papier-maché, about three millimetres thick, are very frequently employed for immobilising purposes. These splints are usually made with flat edges, which may be bent into any required shape, or else flat pieces are used of varying widths. After dipping this material in warm water just before it is to be used, it becomes soft, and can be readily made to fit any part of the body when fastened on with a bandage. The small papier-maché splints are chiefly used for strengthening dressings in which starch is employed.

Metal Splints.—Metal splints are generally made of iron, sheet iron, tin, zinc, telegraph wire, wire gauze, etc., and may be stiff and unyielding or capable of being bent into any shape. Volkmann's sheet-iron splint (Fig. 184) is exceedingly good, and in very general use for the lower extremity. It is a good plan to make this of two parts—an upper and lower—for lengthening and shortening the splint any necessary amount (Mügge). Metal splints which are capable of being bent into any shape are best made of telegraph wire, tin, zinc, or galvanised iron. Flat splints, made of thin tin plate, have been recommended by Solomon and introduced in the Danish army; they

Fig. 184.—Volkmann's sheet-iron splint for the lower extremity.

are thirty-five centimetres long and ten centimetres wide, having at one end two small, three-pronged projections, which are hook-shaped and notched, and at the other two clefts, into which the projections are inserted and secured, thus rendering it possible to make a splint of any desired length. Thin galvanised iron which is capable of being cut with shears has been recommended, especially by Schön and Weissbach, as a material suitable for splints. Schön gives directions for

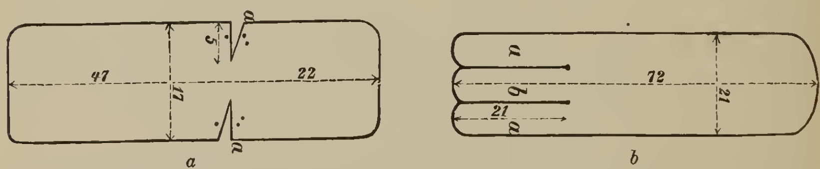


FIG. 185.—Pattern for cutting out a gutter for the arm or leg (Schön).

making excellent splints in a very short time from this substance, and hinge joints, fenestræ, and interrupted spaces can be inserted. In Fig. 185 is represented a simple way of making a gutter splint for the arm and leg.

The gutter splint for the arm (Fig. 185, *a*) is made by cutting out a splint of the desired size and bending it on its long axis so as to form a shallow groove, and then transversely so as to make an obtuse or right angle. Strings are passed through the punctures at *a a*, and tied to maintain the splint at the proper angle. The gutter splint for the leg is cut from galvanised sheet iron, as represented in Fig. 185, *b;* it is then bent on its long axis into a half circle, and the foot-piece is formed by bringing the lateral parts *a a* around behind the middle part, and retaining them in this position by strings or wires.

Wire Splints, made from properly bent telegraph wire or from wire netting, have recently come into considerable favour. Telegraph wire is chiefly used at present for making suspension splints, and in the preparation of the interrupted plaster splint (Figs. 197–199). One of the best-known kinds of wire splint is Smith's (Fig. 186), which is especially well suited for the treatment of compound fractures of the lower extremity. It is made of two nearly parallel bars joined at their extremities and in the intervening space by from two to four movable wire arches or hoops, to which are attached the ropes for suspending the splint. At three places—namely, over the ankle, knee, and hip joints—it is slightly bent, and is then applied to

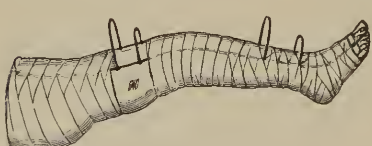


FIG. 186.—Smith's anterior wire splint.

the anterior surface of the limb, to which it is secured generally by a plaster bandage.

Fig. 187.—Esmarch's splint for the arm, made out of telegraph wire.

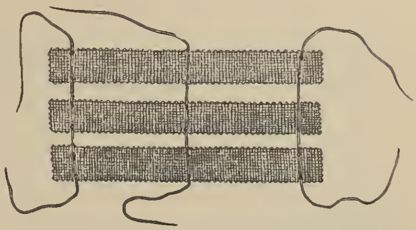


Fig. 188.—Esmarch's wire sieve splint with strings.

Esmarch has constructed a splint (Fig. 187) of telegraph wire for the upper extremity, which approaches the character of the splints made of wire gauze gutters for the upper and lower extremities (Figs. 170, 171). Woven wire is also used for making splints which can be bent into different shapes. Esmarch has recommended the use of long strips of wire lattice for splints (Fig. 188), and from this material it is very easy to make a splint similar to Bonnet's stocking (Fig. 172). Cramer's lattice-work splint, made of iron wire tinned over, is exceedingly good both for ordinary practice and for army surgery. These splints can be bent into any shape, and can be made to fit over any dressing or any part of the body (Fig. 189), and they can be lengthened by fastening one or more together. By taking out some of the cross-pieces and bending the lateral bars the splint can be made interrupted, or can be bent at any angle (Fig. 189, *d*, *e*). Neuber has recommended splints made of glass (Figs. 190, 191), as particularly good for cases where an antiseptic dressing is left in place for a considerable time. They are transparent, and permit all parts of the dressing to be inspected without disturbing the limb. Glass splints

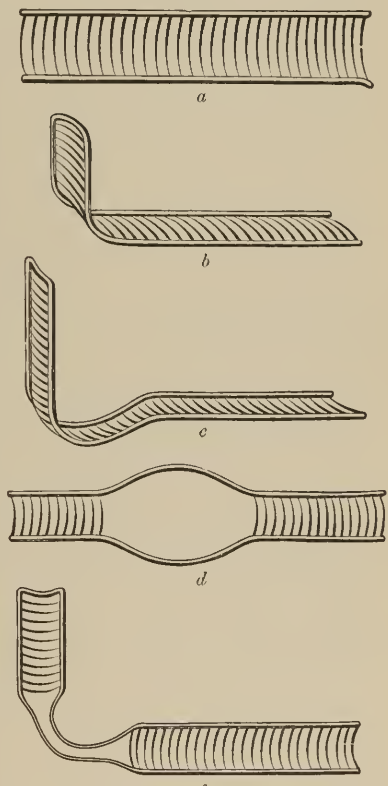


Fig. 189.—Pliable splints made of iron wire tinned over (Cramer).

are comparatively cheap, very clean, and not so easily broken as one might imagine. Gluck has had splints made of glass, porcelain, and earthenware.

Plastic Splints.—Moulded splints are prepared by wetting or heating the material of which they consist, and when it has become soft and

Fig. 190.—Neuber's glass splint for the upper extremity.

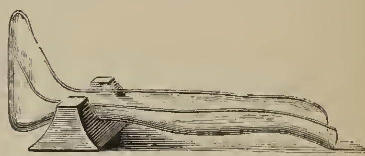


Fig. 191.—Neuber's glass splint for the lower extremity.

plastic it is made to fit snugly over some particular portion of the body by the aid of a roller bandage. After the material becomes dry or cold, whichever the case may be, a hard, unyielding splint results which fits very closely. Such splints may be made in the shape of strips of from two to four fingerbreadths in width, or in the shape of a gutter which may surround a half or the entire circumference of a limb.

Papier-maché.—In the preparation of these splints ordinary papier-maché can be used, though it only possesses a moderate amount of firmness when dry. The prepared papier-maché of P. Bruns is better, and consists of ordinary papier-maché which has been impregnated with some hardening substance, generally shellac. When this preparation is warmed in a hot oven, or wet in boiling water, it becomes soft, and capable of being moulded into any shape in a very few minutes, and subsequently becomes as hard as wood in from five to ten minutes.

Plastic Felt.—Pliable felt can be used in a similar manner, and P. Bruns describes its preparation as follows: A sheet of ordinary felt, from five to eight millimetres thick, is soaked in a solution consisting of one part shellac to one and a half parts of alcohol until it has become completely saturated, or until the felt will absorb no more of the solution. (It takes up about four times its own weight.) It is then allowed to dry, and from this material excellent splints can be made in the shape of flat strips, or gutters, or cases. After cutting the piece of plastic felt into the proper shape, it is dipped into water which is almost boiling, or stroked with a hot flat-iron or laid on a hot stove-lid, which causes it to become as soft as any ordinary unimpregnated felt. The softened felt is then applied with a roller bandage to the limb, which has been previously covered with a bandage or with cotton, and in a short time this splint becomes as hard as a board. F. Schwarz has used moulded felt in Billroth's clinic, as a substitute for more expensive

and complicated contrivances, with the very best results (Wien. med. Wochensch., 1886, No. 37.)

Gutta-percha.—Gutta-percha can be used in a similar manner for making straight, gutter, or case splints. Gutta-percha, or the dried sap of an East Indian tree (*Isonandra gutta*, Sapotacee), was introduced in Europe in 1843, and was first used for treating fractures in England in 1846, though it had been employed for this purpose in Borneo a long time previously. When gutta-percha is warmed in hot water it becomes soft and capable of receiving any shape, and then hardens when it cools off, in about fifteen minutes. For making straight, gutter, or case splints of gutta-percha, sheets of this material are cut into the proper form and softened by immersion in water at a temperature of 75° to 85° C. The splint is then allowed to cool off slightly, and after being modelled into the shape required to fit the particular extremity, which has been previously encased in a flannel bandage, it is kept in place by a wet roller bandage. By gluing together the edges of two gutters a circular splint may be made. Gutta-percha is not affected by water, blood, pus, or urine, but it is expensive, and on this account has not been very generally used.

Caoutchouc Splints.—The black, stiff splints made of caoutchouc are also very good, and can be made to assume almost any form by warming them in hot water.

Leather.—Ordinary leather is an excellent material for making straight or case splints; it should be soaked in water and applied to the limb with a roller bandage while in a wet condition, when it is capable of being moulded.

Paraffin.—Paraffin has been recommended for splints, but it is hardly firm enough, and is very apt to cause an eczema. The plaster splint is referred to in § 54 (Plaster Dressings).

The Author's Plastic Splint.—I have had made an excellent plastic material for the manufacture of splints; it is prepared from the fibres of an African plant, and can be had of the firm of F. Flinch, in Leipsic. A piece of this material is cut of the proper shape and dipped in hot or boiling water, and is thus made so soft that it can be moulded into any form. After a short time this splint becomes very hard.

Cellulose Splints.—R. de Fischer has advised the use of a hardening material for splints made of cellulose. Thick, flat plates of cellulose are manufactured for this purpose having the outline of the different limbs, and strengthened on one side with water glass. This side of the splint is then, before use, painted over with nearly boiling water, which causes the material to become immediately soft and pliable. The splint is applied wet side out, and fastened in position with gauze bandages which have been saturated with

cold water. These splints can be strengthened by impregnating them with water glass on both sides. They are said to possess the advantage of simplicity, rapidity in hardening, lightness and durability, and, furthermore, cost very little. They are manufactured by the apothecary in Triest, Karl Zanetti.

Extension Splints.—Before the introduction of extension by weight, extension splints were employed, and they will be referred to in their proper place.

Articulated Splints.—Jointed splints are those consisting of two or more ordinary splints united by a joint or some material capable of bending, such as caoutchouc, cloth, leather, etc. A jointed splint can be fastened at any desired angle, or can be left movable, permitting free motion in the extremity to which it is applied.

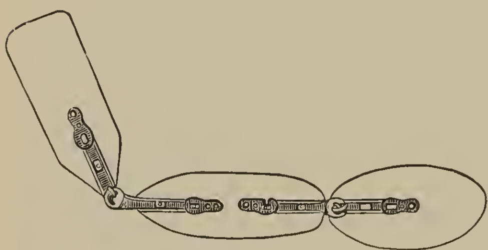


Fig. 192.—Heine's disjointable articulated splint for the upper extremity.

There is a great variety of these articulated splints, the best one probably being Heine's (Fig. 192), though Bidder, Lücke, and others have constructed very excellent splints. These articulated splints can be used for exerting a gradual extension on contracted joints, for overcoming contractures of the muscles and

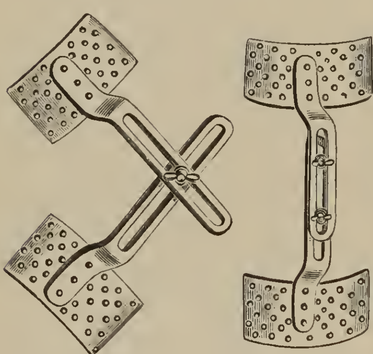


Fig. 193.—Adjustable clamp apparatus.

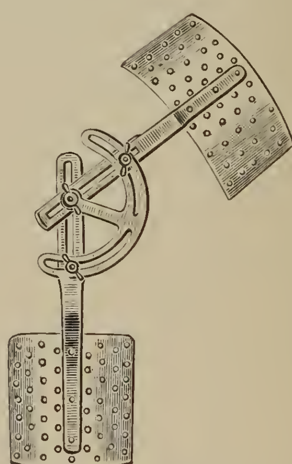


Fig. 194.—Clamp apparatus provided with a joint.

soft parts, and for the after-treatment of resected joints as a supporting apparatus.

Stillmann has also recommended an excellent adjustable brace, which permits motion in the joint to which it is applied, and which can be readily included in a plaster dressing (Figs. 193, 194). Besides all these appliances which have just been described, a great number of complicated apparatus for securing parts in their proper position have been devised and recommended, but the majority of them can be easily dispensed with. Later on we shall become acquainted with several simple contrivances in the way of dressings and braces for treating particular diseases and injuries, but it has been intended at present to give only a brief review of the most useful appliances which are at our disposal.

Improvised Dressings of the Battle-field.—In times of war it may become necessary to improvise dressings and splints out of whatever materials may be at hand. J. Port has written a book on this subject (Stuttgart, Ferd. Enke, 1892), in which are a number of illustrations and descriptions of materials which can be used as surgical dressings.

Apparatus for Home Gymnastics.—Brief mention should be made in this place of the different kinds of apparatus used for gymnastic purposes which should always be found in every hospital. It would take too much space to describe them except in a very general way. L. Ewer has lately recommended a house-boat which is a very good substitute for rowing on the water. It forms an excellent addition to the number of contrivances for home gymnastics (see Illustr. Monatsch. für artz. Polytech., Feb., 1889). The machines invented by Zander, of Stockholm, afford many kinds of gymnastic exercise which are exceedingly useful in some cases, and their place cannot be supplied by either massage or passive motion.

CHAPTER V.

THE APPLICATION OF IMMOBILISING DRESSINGS MADE OF MATERIALS WHICH GRADUALLY HARDEN.

The application of extension dressings.—Plaster dressings.—Dressings of tripolith, starch paste, gutta-percha, and felt.—The methods of applying extension dressings.

§ 54. **Immobilisation Dressings of Hardening Substances.**—Dressings for producing immobilisation are used for fractures, inflammations in joints, and after many operations—for example, in the after-treatment of resections and osteotomies, etc.; they serve the purpose of preventing movement in the part of the body under treatment. Even in ancient times attempts were made to form immobilisation dressings from substances which would subsequently harden, but the methods were imperfect. To Larrey, the distinguished army surgeon of Napoleon I., belongs the honour of having generally introduced those immobilising dressings which were applied in the soft state and then allowed to harden. Larrey soaked the dressings for twenty-four to thirty-six hours in a mixture made of albumen, liquor plumbi subacetatis, and spirits of camphor. This somewhat tedious procedure was supplanted by the starch dressing invented by Seutin in 1834. As the starch dressing took a long time to harden, attention was directed to some more rapidly hardening material, and gypsum was taken up, a substance which had been employed by the Arabian physicians. The honour of introducing the gypsum dressing and the methods of applying it is due to the two Dutch physicians, Mathysen and Van der Loo. Numbers of other hardening substances, such as water glass, tripolith, etc., have also been used in the same way.

The Gypsum Dressing.—Amongst all the materials employed for making an immobilising dressing there is none better than gypsum, possessing, as it does, the power of rapidly becoming hard. Gypsum, or plaster of Paris, is hydrated sulphate of calcium ($CaSO_4 + 2H_2O$). The gypsum used in dressings is burned or dehydrated, and after mixing it with water it hardens in a few minutes to a solid mass, forming with water a firm chemical combination. The plaster dressing can be

applied in many different ways, the best being in the form of plaster bandages. For this purpose bandages, preferably of gauze, are impregnated with dry gypsum powder by rolling them in the latter and working it into the meshes of the gauze. Soft mull bandages can also be treated in the same way. The application of the gypsum dressing is begun by smoothly enveloping the particular portion of the body with a soft mull or flannel bandage, or with a thin layer of cotton, over which is placed a soft mull bandage. In cases where it is necessary, the extremity may first be greased with oil, lard, or vaseline, to prevent the plaster from sticking to the hairs; bony projections should be covered with a little cotton, to avoid pressure at these points; and, above all, one must be careful to apply the bandages loosely, so that after drying they do not become too tight. Cotton hose can also be used beneath the gypsum; it is drawn over the extremity like tights; it is cheap, and fits exceedingly well without forming wrinkles. When necessary, two or three layers of this material may be put on over each other. The roller gypsum bandages are then allowed to soak in water about a quarter of a minute, or until no more air bubbles are given off. The bandage is then squeezed dry and applied to the part in question as loosely as possible. It should never be drawn tight, as this will cause the bandage to become too narrow, and may subsequently impede the circulation in the limb. There is no need of making a reverse with the gypsum bandage, as a few wrinkles do no harm and can be smoothed out by rubbing the bandage with the hand, and thus causing the dressing to conform accurately to the shape of the limb. After about three or four layers of gypsum bandage have been applied, a thin layer of gypsum paste can be added; it is made by mixing together gypsum powder and water in about equal proportions. This layer is spread on and smoothed over with the palm of the hand, the smoothing process being continued until the dressing looks as though made in one piece. The gypsum paste should not be put on too thick, for fear of making the dressing very heavy, and I frequently do not use it at all. Plenty of bandage and not too much plaster is my maxim. The edges of the dressing are best treated by turning up the projecting underlying material (cotton or bandages) like a cuff and securing it to the outer surface of the splint with a turn of the plaster bandage or a little of the paste.

Even while the bandages or outer layer of gypsum paste are being smoothed down with the hand, it will be noticed that the dressing has become firmer. In the next few minutes it becomes noticeably warm and at the same time perfectly hard, but not till two or three hours later will the dressing be completely dry. By the addition of some

crystalline substance, like chloride of sodium or alum, the hardening of the gypsum can be accelerated. If it is desired to make the plaster dressing water-tight, its external surface can be painted with a solution of resin in ether—one to four (Mitscherlich)—or a water-glass bandage may be placed over the gypsum; this latter method is the best. It makes the gypsum dressing, particularly when applied to children, exceedingly durable. For increasing the strength of the plaster dress-

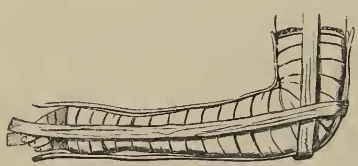


Fig. 195.—Thin splint of wood used for strengthening a plaster-of-Paris dressing.

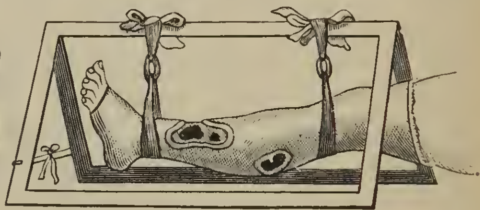


Fig. 196.—Fenestrated plaster dressing, suspended in a wooden frame.

ing the latter is often made to include thin, pliable strips of wood (Fig. 195), or splints made of papier-maché, wood, zinc, or wire. If it is not desirable to cover in some portion of the body by the plaster dressing on account of wounds, fistulæ, etc., a fenestrum (Fig. 196) can be cut out over this portion, the location of which may be previously indicated by placing over it a piece of cotton or a flat disk having a projecting nail. The edges of the fenestrum can be smoothed off with a little plaster paste or asphalt, to prevent fluids such as pus from gaining access to the under surface of the dressing. When a considerable portion of an extremity, such as the knee- or elbow-joint, is to be left out of the splint, two plaster cases should be applied, one, for example, to the thigh, the other to the leg, joined together by an iron rod, which can also be covered with plaster (Fig. 197); telegraph wire can be used in the same manner. Under other conditions, when, for instance, one wishes, at the same time, to suspend the extremity, another plan is carried out which is represented in Figs. 198 and 199. Two plaster cases are applied to the extremity while it lies upon a suitable splint,

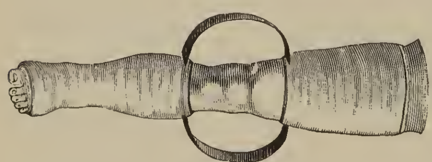


Fig. 197.—Interrupted plaster dressing (for the knee).

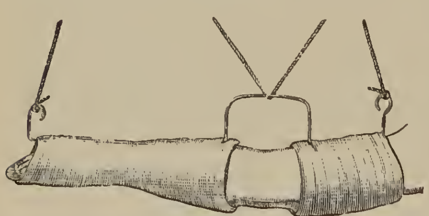


Fig. 198.—Interrupted plaster dressing, suspended (upper extremity).

and a telegraph wire, having been bent into proper shape, connects the two separate bandages on the dorsal surface of the limb and is covered by plaster bandages (see Figs. 207, 208, 209). In the same way two plaster cuffs can be provided with a hinge so as to form a joint, which is useful in the after-treatment of a resected elbow (Heine).

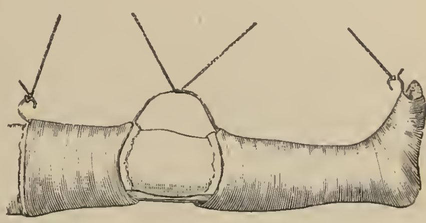


Fig. 199.—Interrupted plaster dressing, suspended (lower extremity).

Gradual stretching of Contracted Joints by the Plaster Dressing.—The plaster dressing can also be used for gradual extension of contracted joints. A plaster case is applied to the lower extremity and an oval-shaped fenestrum cut over the region of the anterior surface of the knee, and at the same time the splint is cut behind transversely across the popliteal space. Day by day continually larger pieces of cork are then wedged into the posterior line of division in the splint, and thus the knee-joint is gradually extended.

Gypsum Dressing combined with an Antiseptic Dressing.—The great advances in modern aseptic surgery render possible the frequent combination of plaster with antiseptic dressings. After osteotomy, for instance, of the femur, we cover the open wound with an aseptic protective dressing and then place over this a plaster splint, which is left undisturbed till the wound has healed, or from four to six weeks. We often adopt a similar practice in the after-treatment of resected joints, allowing the wound to remain partially open, or not sutured tight. In other cases of joint resection the plaster bandages are not placed over the antiseptic protective dressing till about three to five days after the operation, when the drains are taken out. In compound fractures the plaster splint is combined with the antiseptic dressing at the earliest possible moment. Bergmann's and Reyher's experiences show that gypsum dressings will become of the greatest use in army surgery. These surgeons obtained most excellent results, during the Russo-Turkish war, from combined antiseptic and plaster dressing for the treatment of gunshot wounds of bone. In addition to the plaster bandage dressing, as it is ordinarily described, mention should be made of the following modifications:

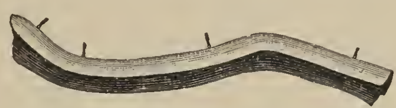


Fig. 200.—Gypsum-hemp splint (Schönborn and Beely).

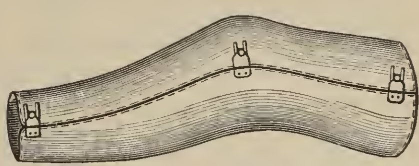


Fig. 201.—Case for the lower extremity, with straps, buckles, and a hinge-joint on the opposite side.

Modifications of the Gypsum Dressing.—Compresses, pieces of cloth, or parts of the patient's clothing, are dipped in plaster paste and either laid

around an extremity or fastened on with bandages after previously enveloping the limb in some buffer dressing. These gypsum cataplasms are highly recommended by Pigoroff, Adelmann, Szymanowski and others for making a hasty dressing to suffice during transportation of the patient. Beely and Schönborn dip strands of hemp in plaster paste, thus making gypsum-hemp splints to which buttons can be attached for purposes of suspension (Fig. 200). Splints which are made in a similar manner with cotton are more comfortable, and are adapted especially for making Braatz's spiral splint for fracture of the radius (see Spec. Surg.). Cotton impregnated with gypsum, or the gypsum plates of Fickert, are dipped in hot water before they are applied to the limb. They harden after some eight to ten minutes. Gypsum powder is also sewed up in a sack, and when soaked in water it forms a mass which readily becomes moulded to the limb, and when dried makes a splint which can easily be taken off (Zsigmondy). By sewing together two of these sacks full of plaster longitudinally upon one side and laying them around an extremity and then wetting them, a gypsum splint is formed having the sewed connection between the two bags as a hinge to facilitate its removal from the limb. In a similar manner immobilisation appliances can be made in two or more parts which can be fastened on a limb with bandages or secured with straps and buckles (Fig. 201). In this way most excellent splints can be fashioned of gypsum or other hardening material, such as waterglass, and also many kinds of supporting apparatus can be substituted for those manufactured by instrument makers.

Auschütz advises that the straw splints which have long been employed by stretcher bearers as a transportation dressing be soaked in plaster paste and bound on with a wet gauze bandage. The plaster cast is the oldest method of applying the gypsum dressing, but is at present no longer used. It originated in the Orient, was employed by the Arabians of ancient times, and was very generally used in Europe at the beginning of this century, especially by Froriep and Dieffenbach. The skin of the extremity was first covered with oil and then enclosed in a wood or sheet metal case which was poured full of plaster paste. Finally, the limb was taken from the case surrounded by the plaster mould.

Back Support.—For the application of the plaster dressing to the lower extremity, and particularly to the thigh and pelvis, extension and supporting appliances are of great utility. They render the pelvis accessible on all sides, and prevent a fractured femur from becoming shortened. The simplest form of pelvic support is represented in Fig. 117; it is Volkmann's cushioned support, which is placed under the sacrum. A footstool used in the same way forms an excellent back rest. The patient is secured in the horizontal position, with extension applied to the leg and counter extension to the axilla. Billroth, Bardeleben and others have invented excellent back rests.

Extension appliances are sometimes very useful accessories in applying a plaster splint to the thigh, especially if the fracture is oblique and there is marked shortening. Lücke, Heine and Bruns have in-

vented extension appliances for this purpose. Pulleys are used, particularly for the lower extremity, in the application of plaster splints. Special contrivances for extension are, as a rule, unnecessary, and the hands of an assistant will ordinarily be found sufficient. Plaster dressings are applied to the thorax chiefly in treating fractures of the upper end of the humerus (Fig. 202). A plentiful amount of cotton padding, with a wad of cotton in the axilla, is first applied and secured with a mull bandage, while the forearm is held across the thorax with the elbow bent at a right angle; then the plaster-splint dressing is placed over the padding, enveloping the thorax, the forearm, and the fractured arm.

Fig. 202.—Gypsum bandage around the shoulder, thorax, and arm for fractures of the upper part of the humerus.

Removal of Plaster Splints.—*Plaster splints or dressings are taken off* with the assistance of a knife made especially for the purpose (Fig. 203), and with shears (Fig. 204, *a*, *b*). Small ordinary saws, as well as circular saws, have also been recommended for this purpose. The plaster knife should be held with its edge somewhat at an angle to the splint, so as to cut it obliquely to the external surface; or two oblique longitudinal incisions are made in the plaster forming a V-shaped gutter. The deeper layers of the splint should be cut with the plaster shears. By moistening the whole splint with water, or only along the line where it is to be cut, the cutting process is made much easier. After the plaster dressing has been cut through longitudinally, the edges of the incision are pulled apart and the limb is lifted out. Plaster splints which have been cut and taken off may, when desired, be replaced and used again. In such cases it is best to connect the

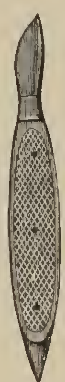


Fig. 203.—Knife for plaster dressings.

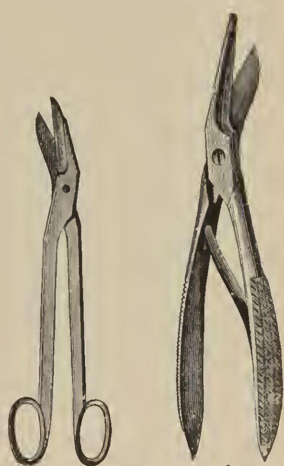


Fig. 204.—Scissors for plaster dressings.

edges with plaster paste or adhesive plaster, over which plaster paste is applied, and thus the edges of the splint are less likely to become separated.

Tripolith Dressing.—Langenbeck has recommended tripolith as a substitute for gypsum or plaster of Paris. Tripolith is a greyish, cement-like substance consisting of gypsum with a little silicate of aluminium and charcoal or coke. The properties of tripolith are in general the same as dehydrated gypsum, but tripolith, according to Langenbeck, is somewhat lighter and cheaper than gypsum; it also hardens a little more rapidly, and when hard will not absorb water. The tripolith dressing is applied with bandages, like plaster of Paris.

The Starch Dressing.—Starch paste was recommended by Seutin, in 1834, for the manufacture of stiff dressings. A starch dressing is easily applied, agreeable to the patient, cheap and light, but it has the disadvantage of requiring from one to three days to become dry, and for this reason starch dressings have been supplanted by plaster in the treatment of fractures. The starch bandage is frequently combined with pasteboard splints in fracture of the arm, and is also used alone in the later treatment of any fracture.

The method of applying the starch bandage is briefly as follows: A padding is laid on the skin in the shape of a flannel bandage, and the bony prominences are protected from too much pressure from the starch dressing by a layer of cotton. A soft mull bandage is applied over the flannel, and then a layer of starch or bookbinders' paste is spread over the mull. Several strips of pasteboard of various sizes are rendered soft and pliable by soaking in warm water, and are included in the dressing in such a way as to encase the limb, leaving short intervals between each strip. The pasteboard is then covered evenly with the starch paste, and over this is placed a mull bandage, which receives another layer of starch paste. Some three to four layers are enough, and the strips of pasteboard can be used in a double layer, especially if they are narrow. Finally, a dry mull bandage is applied to prevent the starch paste from adhering to the clothes, or a bandage in the form of a bag may be used, as well as black silk, to improve the appearance of the dressing. The dressing is cut open with a stout pair of shears, and can then be used as a removable splint in the same way as described for the plaster splints (Fig. 201).

Cotton-Starch and Paper-Starch Dressing.—The cotton-starch dressing of Burggraeve and the paper-starch dressing of Laugier and Heyfelder are modifications of the ordinary simple starch dressing. The latter is made by including strips of paper in the bandages and covering them with starch paste. In the cotton-starch dressing the limb is enveloped in from two to

four rather thick layers of cotton wool, over which is applied the starch-paste dressing, with strips of pasteboard softened in warm water, and made to fit the extremity by wrapping over them a mull bandage in the manner just described (page 222).

The Water-Glass Dressing (Schrauth, Schuh, 1857) is very easily put on, is cheap, durable, hard, and light, and is also impervious to water, but has the disadvantage of requiring twelve to twenty-four hours to harden. It is best to use a freshly made solution of neutral silicate of potassium having a specific gravity of from 1·35 to 1·40. This dressing, like the plaster of Paris, is applied in prepared bandages which have been saturated with water glass having the consistency of syrup. About five to six layers of the water-glass bandages are sufficient. It is best to use a flannel bandage, or cotton and a mull bandage, as padding to lie beneath the water-glass bandages. The skin should be carefully protected from contact with the water glass, as the latter is liable to cause a very obstinate eczema, particularly when old solutions are used. Furthermore, the water-glass bandages should not be carried beyond the limits of the protective padding, as the sharp edges of the splint may cut into the skin. The water-glass splint can also be strengthened by including in it thin strips of wood or other material. It is an excellent plan to mix with the water glass, gypsum, chalk, cement, etc. These substances make the dressing harden more rapidly and render it very firm (Böhm, König, the author). Bandages are soaked in the thick paste and applied as in the plaster dressing, or the paste made from water-glass powder is applied with a brush to the bandages after they have been put in place. At the end the entire dressing can be dusted with the dry powder and painted over with alcohol, which gives it a hard, glassy covering. The water-glass splint is much used in the treatment of inflamed joints, fractures, etc., and can also be made into hinged, removable splints. Kappeler and Hafter have shown that a number of apparatus, artificial limbs, corsets, articulated splints, etc., can be made of water glass.*

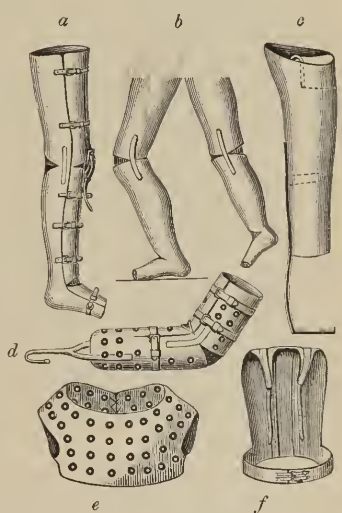


Fig. 205.—Bandages, artificial limbs, and corsets, made of water glass.

* For the further description of these appliances, see Kappeler and Hafter, Deutsch. Zeitschr. für Chir., Bd. vii., P. 129.

(Fig. 205). Fig. 205, *a* and *b*, represent water-glass splints for the lower extremity, provided with straps, buckles, strips of caoutchouc, and fenestræ suitably placed for permitting movement of the joints.

c is a contrivance of Taylor's for use in coxitis (see Spec. Surg.); *d* represents a prothetic apparatus for amputation of the arm; *e* is a corset, and *f* is another of Taylor's devices for kyphosis; *d* and *e* are perforated with holes, to make the apparatus light and accessible to air.

The manufacture of immobilisation appliances from moulded felt and gutta-percha has been described before (see pages 212, 213).

Dextrine Dressing.—Amongst the other materials which have not found any very general use brief mention may be made of the dextrine dressing of Velpeau (1838). It is applied in the same manner as the starch dressing, one hundred parts of dextrine being mixed with sixty parts of spirits of camphor and fifty parts of water. This dressing takes from four to seven hours to dry.

Glue Dressing.—The glue dressing (Vanzetti, 1846) hardens very slowly. Strips of linen or roller bandages of linen or muslin are spread on one side with joiner's glue, allowed to dry, and then rolled into bandages with the glue side out. The bandages immediately before use are dipped in hot water and applied to any desired region over a protective padding bandage. The same procedure can be adopted as in starch or water-glass dressings, which consists in simply saturating bandages and splints with the glue after they have been applied. Thin wooden or pasteboard splints can be incorporated in the dressing to strengthen it.

Magnesite Dressing.—The magnesite dressing is most excellent, firm, and durable. Finely powdered magnesite and water glass are mixed into a thick paste. The method of applying this dressing, which requires some twenty-four to thirty-six hours to dry, is practically the same as for the starch or water-glass dressing—i. e., either the magnesite water-glass paste is painted with a brush over the dry mull bandages, or else the mull or cotton bandages are first soaked in the paste and then applied to the extremity over a padding of flannel bandages.

Cement Dressing.—In the application of the cement dressing a mixture of one part of cement to two to three parts of gypsum is employed, and this is then applied like the gypsum or plaster-of-Paris dressing.

Other Dressings.—The gum dressing (Lorinser) is made of lime or cement dissolved in casein, albumen, gum arabic, glue and other materials by the addition of water.

The gum-chalk dressing of Bryant and Wölfler is made of a paste of gum arabic and chalk powder. There is also a collodion dressing, a resin dressing, with or without wax, a paraffine and stearine dressing, but so far all these have not come into general use.

§ 55. **The Method of applying Extension by a Weight.**—As we shall see later on, permanent extension is much used, for example, in chronic inflammations of joints and in fractures. The method of applying ex-

tension by a weight is the most generally used of all, and for this we have to thank the American surgeons Buck, Crosby and others, as well as the German surgeons Volkmann and Bardenheuer. The pulling of the fragments apart by a weight is very frequently used for the lower extremity in fracture of the femur and for diseases of the hip and knee joints, and consequently we must describe it somewhat at length.

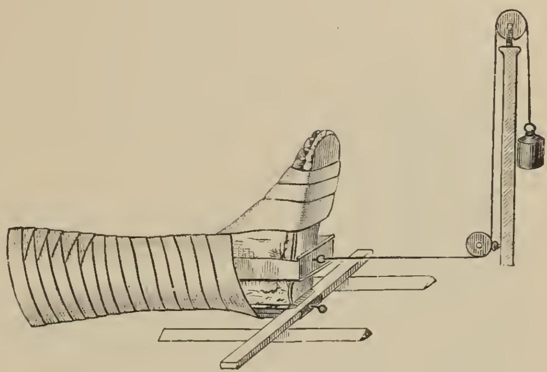


Fig. 206.—Adhesive-plaster extension apparatus.

Extension by a Weight for the Lower Extremity.—The extension dressing for a fracture of the neck of the femur in the form of an adhesive-plaster extension contrivance is begun in the case of adults with the application of a strip of adhesive plaster, from three fingers to a hand-breadth in width, along the inner and outer side of the leg, in such a way that the middle of the strip extends in the form of a loop about a hand-breadth beyond the sole of the foot. Before applying the adhesive plaster it is a good plan to shave off the hairs, to prevent the latter from sticking to the plaster; then strips of adhesive plaster (or a flannel bandage) are placed circularly around the leg over the lateral strips at intervals, or overlapping each other, beginning just above the malleoli and going to the head of the fibula. The free ends of the adhesive plaster, which should reach to the middle of the thigh, are then split longitudinally with scissors into two or three strips,

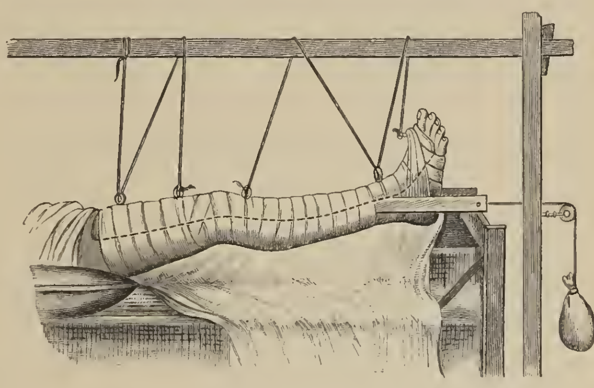


Fig. 207.—Extension with suspension by means of a gypsum-hemp splint or a telegraph-wire splint for fractures of the femur.

which are turned down from the thigh and also secured about the leg with several circular strips of adhesive plaster.* In this manner the lateral strips of adhesive plaster are secured to the leg very firmly. I avoid placing strips circularly around the leg in the region of the head of the fibula, as this practice sometimes has been known to cause a pressure paralysis of the external popliteal nerve. The adhesive plaster must be made of strong material, to withstand the strain put upon it, and consequently it may be advisable to make the lateral strips of two or three thicknesses. In the loop made by the adhesive plaster below the foot a small piece of board is fastened in place to prevent chafing of the skin over the malleoli. Through a hole in the centre of this board is passed the rope to which the extension weight is attached. The rope is fastened to the board by knotting it on the side next the foot, or it may simply be attached by a hook (Figs. 206, 209). The rope to which the weight is fastened for making the extension runs over two rollers fastened to the patient's bed (Fig. 206). This dressing can be made more firm and durable by applying over it a layer of mull bandage, and over this a gauze bandage, or, better still, a water-glass or chalk-water-glass dressing. To lessen the amount of the chafing to which the limb is subjected, and to regulate the position of the foot, it is a good plan to use Volkmann's sliding foot rest (Fig.

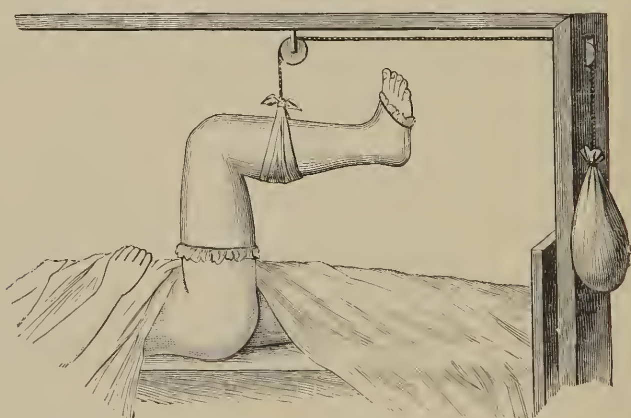


Fig. 208.—Vertical suspension with a plaster dressing, the knee being bent at a right angle.

206), which consists of a tin gutter splint for the leg, padded with cotton or jute, and having a removable foot-piece attached to a wooden cross-bar. The cross-bar slides on two longitudinal strips of wood.

* In this country the strips are not turned down, but left applied to at least half the length of the thigh above the knee, to lessen the traction on the ligaments of the knee-joint.—[*Trans.*]

Other sliding foot rests have been invented by Riedel and Wahl. If Volkmann's contrivance is employed, any hardening dressing, such as

Fig. 209.—Vertical extension for fractures of the femur in children.

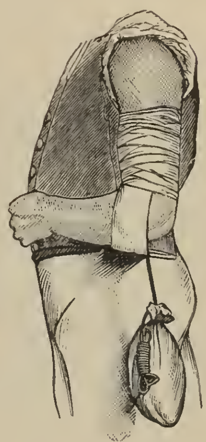


Fig. 210.—Extension at the shoulder by a weight.

the water-glass bandage, must of course be applied so as to include the leg splint. The weight of the body is ordinarily employed for making counter extension, the patient being kept, if possible, in the horizontal position while the foot of the bed is raised by a couple of blocks of wood; or a pelvic or perineal girdle, made, for example, from a rubber bandage, can be carried around

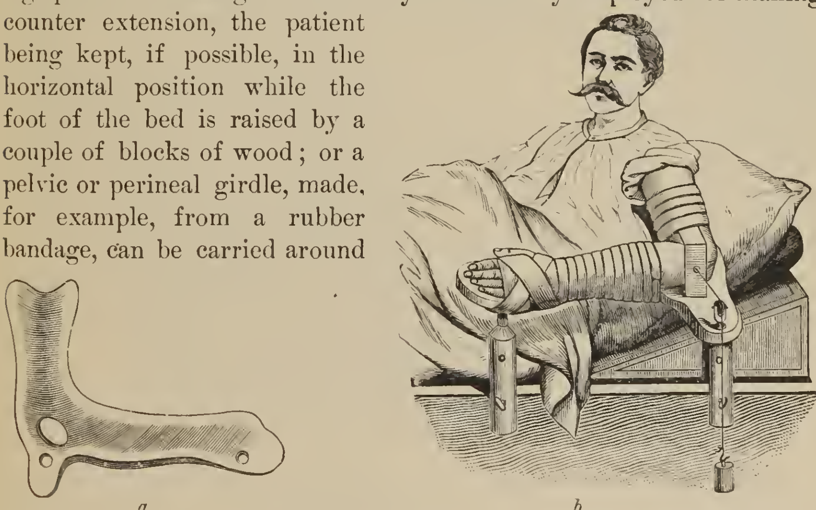


Fig. 211.—Extension by a weight applied to the upper arm (Lossen); *a*, gutter splint.

the patient's perinæum, thence to the head of the bed, and attached to a weight by a cord running over a couple of rollers.

As adhesive plaster is sometimes uncomfortable, and may cause a

troublesome eczema, emplastrum cerussæ may be used in its place; or perhaps a better plan is to enclose the limb in a flannel bandage, and to attach to this extension strips made of pieces of linen cloth; or a strong and not too elastic rubber bandage may be sewed laterally to the turns of the flannel bandage. Extension may also be combined with some one of the various kinds of immobilising dressings, such as plaster of Paris. Recently the cord for exerting the traction has been attached by means of hooks and cross-bars to rubber tubing filled with air applied around the region just above the malleoli.

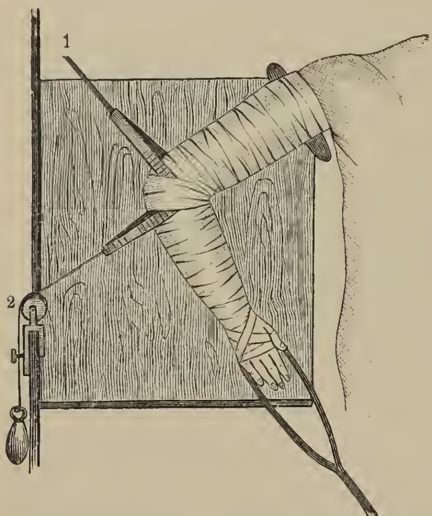


Fig. 212.—Extension by a weight applied to the upper extremity (Hofmokl). In extension by weight of the upper arm the loops 1 and 3 are not used; in case of the forearm 2 is not used; the extension is then made at 3 and counter-extension at 1.

In the after-treatment of cases, such as a hip-joint resection, where extension is only required at night, gaiters are applied reaching to the middle of the thigh and having a leather foot-piece to which is fastened the cord for exerting the traction.

If it is desired to apply extension to the thigh in a somewhat abducted position, as after resection of the head of the femur, rollers can be attached to a board, which may be fastened with screws to any desired part of the bed, while the cord for exerting the traction is carried over a wooden frame placed in the neighbourhood.

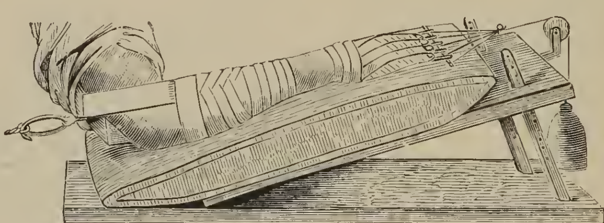


Fig. 213.—Extension of the forearm and hand (Langenbeck).

Frequently, in cases of fracture of the lower extremity, extension is combined with suspension, as illustrated in Figs. 207, 208, and 209. It requires no further explanation.

Extension by a Weight for the Upper Extremity is carried out by means of adhesive plaster applied to the shoulder-joint and arm, accord-

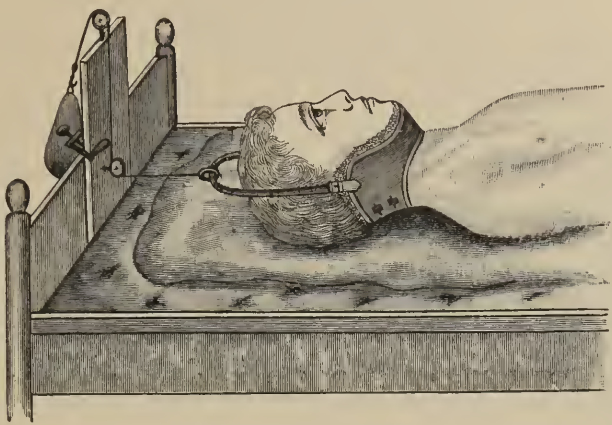


Fig. 214.—Permanent extension by weight by means of Glisson's sling for cases of spondylitis.

ing to the methods of Bardenheuer and Hamilton, or of Lossen or Hofmokl. Extension upon the upper extremity has by no means the importance that it has upon the lower. Hamilton's extension at the shoulder-joint (Fig. 210) is applied by means of adhesive plaster and a

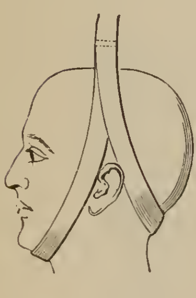


Fig. 215.—Falkson's sling for the chin and back of the neck, made of cerussa plaster and used for extension of the vertebral column.

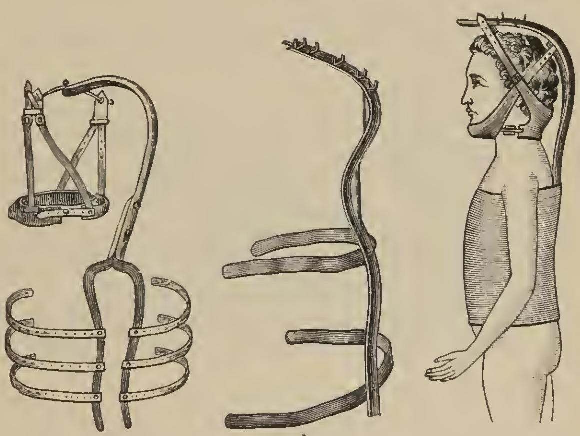


Fig. 216.—Fixation and extension of the cervical vertebræ for spondylitis cervicalis and dorsalis by means of the jury-mast (Sayre).

weight, while counter extension is made with a crutch in the axilla, the crutch being supported by a belt around the waist. Lossen's extension for the arm (Fig. 211) is applied by laying the arm on a splint which is

fastened to the patient's bed. The way in which the traction is exerted by adhesive-plaster strips is represented in the figure and needs no further description. Hofmokl has also devised an excellent apparatus for applying extension by a weight to the upper extremity (Fig. 212). There is seldom any need of applying extension at the elbow-joint, but for the forearm and wrist-joint Langenbeck's method (Fig. 213) can be used. Extension by a weight can also be employed for the metacarpus and fingers by means of loops of adhesive plaster. Extension by suspending the arm is illustrated in Fig. 168.

Fig. 217.—Felt-corset with jury mast for fixation of the head in spondylitis cervicalis.

Extension by a Weight for the Vertebræ.—The following is a brief description of the methods of using extension for the vertebræ: For fractures and tubercular inflammation of the vertebræ, Glisson's leather sling with a metal arch (Fig. 214) is employed, or Falkson's chin-neck sling of emplastrum cerussæ (Fig. 215). E. Fischer's suggestion is excellent: A four-cornered piece of cloth is provided with openings for the face and neck; it is then padded in the region of the chin and back of the neck, and the four corners of the cloth are brought together over the top of the head and connected with the cord used for exerting the traction. Counter extension is furnished by the weight of the body—i. e., the head of the bed is raised, or extension is applied to the legs.

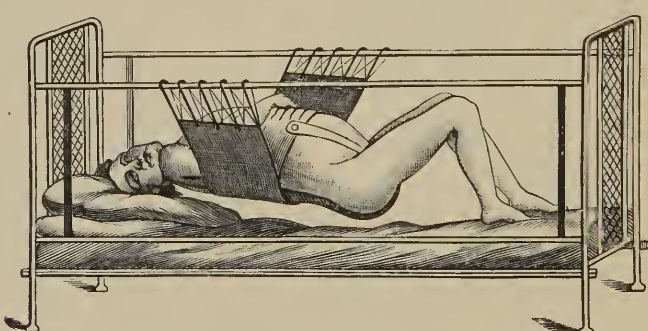


Fig. 218.—Position of the patient in Rauchfuss's hammock in cases of spondylitis tuberculosa.

In cases of tubercular inflammation, for example, of the cervical vertebræ, the latter may be fixed and extended by means of the jury mast corset (Sayre, Figs. 216, 217). For extension of the lumbar and dorsal vertebræ it is best to use the weight of the patient's body by placing him either in a Rauchfuss hammock (Fig. 218) or in a Bar-

well's sling. The methods of applying these different dressings will be described in the Text-Book on Special Surgery.

The Amount of Force to be used in Extension.—The amount of traction which may be employed in the different extension appliances varies with the age of the patient and the nature of the disease or injury. For fractures of the femur and hip-joint inflammations in small children, one to two to three kilogrammes are used; for children from ten to twelve years old, somewhat more; while in adults ten to fifteen kilogrammes may be needed.

Extension by Splints.—Extension by splints is much less used now than was formerly the case. Reference will be made in the text-book on special surgery to the splints used for extension purposes, especially under the treatment of diseases of the hip-joint.

THIRD SECTION.

SURGICAL PATHOLOGY AND THERAPY.

CHAPTER I.

INFLAMMATION AND INJURIES.

The phenomena of inflammation.—The histological changes which take place in inflammation.—Causes of inflammation.—Symptoms of inflammation.—Terminations.—Diagnosis.—Treatment.—Morphology and significance of micro-organisms (microbes).—Injuries in general.—The histological changes which occur in the healing of a wound.—The reaction following wounds and inflammations.—Fever.—Shock.—Delirium tremens.—Delirium nervosum.—Disturbances which may arise during the healing of a wound.—Infection of wounds.—Inflammation.—Suppuration of the wound.—Lymphangitis.—Arteritis.—Phlebitis.—Cellulitis.—Erysipelas.—Wound diphtheria (hospital gangrene).—Tetanus.—Septicæmia.—Pyæmia.—Infection by cadaveric poison.—Other kinds of infection.—(Anthrax; symptomatic anthrax.—Glanders.—Hoof and mouth disease.—Hydrophobia.)—Poisoning by insects, snakes, etc.—Curare poisoning.—Appendix: Chronic microbic diseases.—Tuberculosis.—Leprosy.—Actinomycosis.—Syphilis.

§ 56. **Inflammation.**—The physicians of antiquity recognised the four cardinal symptoms of inflammation: Redness (rubor), heat (calor), swelling (tumour), and pain (dolor). But these outward manifestations do not throw light upon the source and essence of inflammation. The question, where the origin of the process is to be found, has always been a subject of discussion, and the principal part in the production of inflammation has been ascribed in turn to the blood, to the tissues, to the blood-vessels, and to the nerves. Numberless experiments have been performed and the most diverse theories have been advanced to account for the phenomena of inflammation. Virchow founded the *cellular-pathology theory*, according to which an "inflammatory irritation" leads to definite changes in the cells. Cohnheim ascribed it to a probable molecular change in the walls of the vessels, while Recklinghausen and Thoma laid stress upon the vasomotor nerves, and particularly upon their centres located in the inflamed region. Of the various inflammatory irritants or causes of inflammation, micro-organ-

isms and the products of their metabolism should be looked upon as the most important.

Changes in the Circulation in an Inflamed District.—In order to understand the nature of inflammation, it is best first to study what takes place in the circulatory system. Cohnheim has shown how these processes may be watched under the microscope. The intestine of an etherised or curarised frog is drawn out through an opening made in the side of the abdominal wall, and the mesentery is spread out on a slide beneath a microscope. In this way the mesentery, with its vessels, is subjected to the influence of the air and the irritating substances in it. After a short interval an inflammation begins, all the various manifestations of which can be observed from beginning to end, and all the more exactly if the preparation is protected from all bruising, drying, or soiling, etc. The webbing between the toes or the tongue of the frog can be used in the same manner: the tongue is drawn out and fastened with insect pins to a cork rim around a slide, and then by cauterising or scratching the papillæ an inflammation can be produced and the various phenomena studied.

There is first seen a dilatation of the exposed vessels of the mesentery, if that is employed, beginning in the arteries and extending to the veins, and to a less extent involving the capillaries. Simultaneously with the dilatation of the vessels the blood stream begins to flow more rapidly, and this is followed sooner or later, in from half an hour to an hour, by a marked slowing of the current. As a result of this slowing the separate corpuscles can be distinguished in the veins and capillaries, and even in the arteries; and they will be found to accumulate, especially in the veins and capillaries. In the veins, particularly, there will be large numbers of colourless blood-corpuscles in the peripheral portions of the current, and occasionally they will stick to the inner walls of the veins (peripheral stasis of the

Fig. 219.—Inflamed mesentery of a frog; *V*, vein; *A*, small artery and capillaries. The vessels contain white blood corpuscles on their inner walls, some being in the process of emigration; the surrounding tissues contain numerous leucocytes which have already emigrated from the vessels.

white corpuscles or leucocytes, Fig. 219). The red cells, on the contrary, continue to flow along with diminished rapidity in the centre of the stream. Presently, following the peripheral stasis of the white cells, there will be observed a new phenomenon: a point will be seen to project from the external contour of some vein or capillary, and then gradually become larger and more and more prominent (Fig. 220, *a*); and finally this bit of protoplasm will only remain attached to the wall of the vessel by one or more processes, and at last becomes entirely separated, which means that a white corpuscle has made its way out of the vein or capillary (Fig. 220, *b*). Six or eight hours later this process has continued to such an extent that the veins and capillaries are surrounded by these migrated white cells. In addition to these cells, which are usually polynuclear, there will be found small round mononuclear cells (lymphocytes), which, according to Grawitz and Ribbert, are to be regarded as derived from the fixed connective tissue cells, though Baumgarten claims that they are likewise white corpuscles which have migrated from the vessels of the same region (leucocytes). According to Baumgarten, the small mononucleated lymphocyte form of leucocyte is the predominant element in chronic inflammations. Waller was the first (1846) to note the migration of the lencocytes from the interior of the vessels, but his observations had been entirely forgotten when Cohnheim rediscovered this phenomenon in 1867.

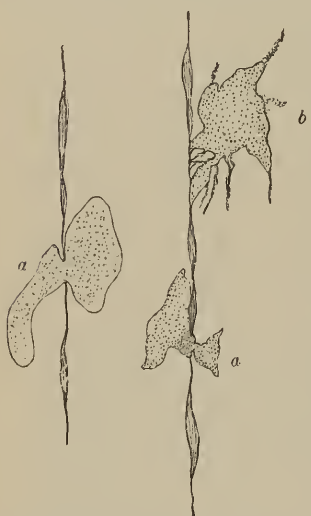


Fig. 220.—Emigration of leucocytes: *a*, Incomplete, *b*, complete emigration (schematic).

Red blood disks also pass through the walls of the capillaries, but not of the veins, for in the capillaries both classes of cells come in contact with the walls, and are not, as in the veins, confined to separate parts of the blood current. The proportion of red cells contained in the exudate varies; some lie here and there on the outer wall of the capillaries, some collect in tiny punctate hæmorrhages, and some are washed away in the stream of transuded serum. No blood-corpuscles migrate through the walls of the arteries.

The time required for a white cell to pass through the wall of a capillary or vein varies, and the same holds true as to the passage (diapedesis) of a red cell through the wall of a capillary. Sometimes the movement is slow, while at others a few minutes are enough for

three, four, or more cells to escape one after the other at the same spot; and immediately thereafter the blood stream, with its corpuscles, flows on normally past the point where they have escaped.

Significance of the escape of the Leucocytes.—As Leber has demonstrated, the escape of the leucocytes from the vessels is not unregulated, but they obey an attraction towards the place of irritation similar to that observed by Pfeffer, O. Hertwig and Engelmann in vegetable cells and bacteria upon which certain chemical substances exert a peculiar power of attraction (chemotaxis). The substances which act in this manner on bacteria are the salts of potassium, peptones, and especially all nutritive substances; while other substances, such as free acids and alkalies or alcohol, have a repellent power (negative chemotaxis). These facts, which Pfeffer has demonstrated experimentally for the fungi, have a most important bearing upon the subject of inflammation. This power to attract, or chemotaxis, influences or even controls the movements of the leucocytes in the tissues towards the focus of inflammation, also the actual migration of the cells from the vessels and later the formation of new vessels at the same point. The leucocytes are especially attracted by the bacteria, or rather by the products of their metabolism. According to Buchner, the protoplasm of bacterial cells contains substances which exert this attraction upon the leucocytes, the so-called bacterial proteins which Nencki studied as early as 1880 in certain kinds of bacteria, from a purely chemical standpoint. These proteins will produce inflammation or suppuration only after they have become separated from the bacterial cell, consequently only after the latter has died or become diseased. The assembling of cells at the seat of inflammation is to be regarded as essentially a protective measure taken by the organism for the purpose of defending itself against external noxious influences. The leucocytes serve, perhaps, to eliminate, to liquefy, and to separate the inflammatory focus from the healthy living tissues (Leber).

Increased Exudation.—Accompanying the migration or extravasation of blood-cells there is an increased transudation of the liquid elements which infiltrate all the surrounding tissues. This increases the amount of the lymph current until the lymph channels become inadequate for carrying away the transuded liquid, and then results a swelling of the part of the body which is inflamed. Partly as a result of their own power of locomotion, and partly carried along by the transuded fluid, the white blood-corpuscles become distributed through the tissues at ever-increasing distances from the vessels out of which they have wandered. Finally, both the corpuscles and the exudate make their way to the surface of the mesentery, and there the exudate

coagulates, forming a so-called false membrane, which is filled with numberless white blood-corpuscles and a few red ones.

Corresponding to the great number of leucocytes which it contains, the inflammatory exudate is very rich in albumen, while the exudate which follows passive congestion is not (Hoppe-Seyler, Lassar). Only in cases of mild inflammation, or in the early stages of others, does the exudate contain a small number of cells.

According to the character of the inflammatory exudate, we distinguish it as serous, fibrinous, croupous, diphtheritic, suppurative, hæmorrhagic, and ichorous.

Proliferation of Connective-tissue Cells in Inflammation.—Not all of the cells which are found in inflamed parts are migrated leucocytes. The fixed connective-tissue cells proliferate by rapid division, and contribute notably to the cellular infiltration of the inflammatory focus.

According to Stricker and Grawitz, the intercellular substance of the tissues undergoes a cellular metamorphosis when inflamed, reverting to its embryonic cellular state. The cells also which have hitherto lain dormant in the stroma (dormant cells, Grawitz) are said to awake to renewed activity. The views which Grawitz has expressed concerning the process of inflammation are of great scientific interest, but they greatly lack the support of observed facts, and have not yet met with general acceptance.

Inflammation from Croton Oil.—The manifestations of inflammation just described can also be produced by irritating the frog's tongue with very dilute croton oil (1·50 of olive oil), by cauterising it with a stick of nitrate of silver, or by applying a ligature to temporarily shut off the blood from the vessels of the tongue. Precisely similar phenomena can be observed in warm-blooded animals—for instance, in the mesentery of a small rabbit. All the gross changes which take place in an inflammation can be produced in a rabbit's ear by painting it with croton oil, cauterising it, applying a ligature, or by subjecting it to heat or cold, as by dipping it in hot water or lightly freezing it with a cooling mixture. An ear which has been subjected for even a few minutes to a temperature of 56° to 60° C. (140° to 147° F.), or −18° to −20° C. (−1° to −4° F.), will inevitably necrose. After a rabbit's ear has recovered from the effects of croton oil, it gains, according to Samuel, a kind of immunity as regards this drug—i. e., it reacts to a subsequent application of the oil much less violently than an ear which has not been so treated.

The phenomena thus described—viz., the simple congestive hyperæmia, the extravasation of the corpuscular elements from the capillaries and veins, the increased exudation terminating in stasis and later in death of tissue, and also the proliferation of the fixed connective-tissue cells—form a group of symptoms which we are accustomed to designate by the name of inflammation.

Cause of Inflammation.—Cohnheim ascribed the cause of all these phenomena and the essence of inflammation to molecular changes in the walls of the vessels. According to him, these molecular changes increase the adhesiveness, and consequently the friction, between the blood and the walls; hence the slowing of the stream. Exactly what kind of a change is produced in the vessel walls in inflammation is not clearly understood; it cannot be detected with the microscope, and we can only say that the walls become more pervious, enough so to occasion the increase in exudation notwithstanding the diminution of the blood pressure which takes place especially in the capillaries. Winiwarter has shown that a colloid liquid, such as a solution of glue, can pass through the inflamed walls of blood-vessels even when the pressure is subnormal. A rupture, an interruption of continuity in the wall of the vessel, permitting the escape of the leucocytes and of a few red corpuscles, certainly does not take place. Likewise, Arnold's theory that in inflammation the natural stomata between the endothelial cells become enlarged and that new ones form, is, as Cohnheim always maintained, incorrect. Cohnheim's comparison of inflammatory exudation with filtration seems very appropriate. Under normal conditions only a small amount of a thin liquid can pass through the filter of the vessel wall; but when inflammation sets in the filter becomes coarser and permits not only denser solutions to pass through, but also formed elements, the blood-corpuscles. The change produced in the vessel wall by inflammation is, according to Cohnheim, probably chemical.

But all the manifestations of inflammation cannot be explained by the condition of the vessel walls, which Cohnheim thought was sufficient. The investigations recently made by Recklinghausen, Arnold and others go to show that Cohnheim's theory needs certain limitations in view of the fact that a distinction must be made between the exudation of fluid constituents of the blood and the emigration of white corpuscles. Thoma's researches have shown that a primary alteration in the walls of the vessels is not always the cause of the emigration. A simple disturbance of circulation following an irritation of the local vasomotor centres produces a peripheral stasis and an emigration of leucocytes. But the latter phenomenon will only last a brief time in those cases in which there is no other influence at work; the vasomotor nerves resume their function, and the peripheral slowing of the current and the escape of the leucocytes cease. If the disturbances in innervation are more marked, and if the emigration is allowed to go on for a longer time, a secondary change in the walls of the vessels takes place. But in these cases the disturbance in the innervation of the vessels is the primary event, and not the alter-

ation in their walls. Thus Recklinghausen seems to be correct in ascribing to the vasomotor nerves, and particularly to their terminal local centres, an important part in the inflammatory process, and especially in the emigration of the leucocytes. Herpes zoster and other diseases resulting from disturbances in innervation go to prove the truth of this theory. Samuel has shown that the inflammatory process becomes more severe when there is vasomotor paralysis. Moreover, the emigration of leucocytes is affected in both a positive and negative way by the above-mentioned chemotaxis. On the other hand, the exudation of the fluid elements of the blood during an inflammation can only be explained by a change in the permeability of the walls of the vessels, located in either the endothelial cells or the cement substance between them.

According then, to our present knowledge, we must look for an explanation of the phenomena of inflammation (1) in vasomotor changes in the vessels, or, rather, in disturbances within the vasomotor centres in the walls of the vessels; (2) in an increased permeability of these walls; (3) in the positive (attracting) and negative (repelling) chemotaxis of the inflammatory focus, and finally (4) in the reactionary proliferation of the cells in the inflamed tissues. It is an exceedingly difficult matter to give an exhaustive and satisfactory definition of inflammation.

Other Theories of Inflammation.—Before Cohnheim, Recklinghausen, and Thoma had established the above explanation of inflammation, a great variety of theories had been advanced, the most important being the neurohumoral (Cullen, Henle) and the cellular (Virchow). According to the former, the nature of inflammation or the disturbances in the circulation are explained either by a contraction or dilatation of the afferent arteries, produced reflexly through stimulation of the sensory nerves. We have seen that nervous influences really do play an active part in the process of inflammation.

Virchow's cellular theory of inflammation is based upon the changes in the life of the cells brought about by the primary causes of inflammation. Virchow regarded the cells of the tissues as the essential elements in the inflammatory process. As a result of the inflammatory irritation they were caused to swell and proliferate and form pus corpuscles. These altered cells are supposed by Virchow to exercise a kind of attractive power for the contents of the vessels, producing increased exudation.

Samuel thinks that inflammation is due to a changed relationship of the blood, the walls of the vessels, and the tissues to each other. Recklinghausen agrees with him in general.

Landerer thinks that the inflammatory changes in the circulation depend upon a disturbance of the normal balance between the blood pressure and the tension of the tissues, caused by a change in the elastic properties of the tissues and the walls of the vessels. This change in elasticity, he is inclined to

believe, is the primary factor, though he admits that the walls of the vessels may become primarily diseased.

No one of these theories can by itself explain the nature of inflammation, especially if that theory is based upon only a single manifestation of the inflammatory process and attempts to solve the problem from this standpoint alone. Consequently, it is evident why Cohnheim's attempt to explain inflammation by a change in the walls of the vessels is to-day regarded as inadequate. No value can be attached to any theory which does not include a correct explanation of the changes produced under the stimulus of inflammation in both the solid and fluid elements of the tissues (cells, nerves, and walls of the vessels), and does not consider these in their causal relationship to one another.

§ 57. **Causes of Inflammation.**—The *causes of inflammation* are very numerous. Any influence which produces a change in the walls of the vessels in any particular part of the body, in the manner above described, may give rise to inflammation. We recognise principally the following classes of inflammation which differ in point of etiology:

1. Inflammation from mechanical causes (every kind of traumatism).
2. Inflammation following the action of extremes of temperature (thermal inflammation; burning, freezing).
3. Inflammation due to chemical causes (toxic bacterial infection).

Under the heading of toxic inflammations belong not only those which are produced by the action of some particular chemical such as mercury, sulphuric acid, etc., but it includes all inflammations caused by the absorption of chemically changed, decomposed, or putrid substances of a gaseous or liquid nature. Inflammations following the stings of insects, such as bees, and those from the bites of serpents, all come within the class of toxic inflammations. Advancing a step further, we come to the infectious inflammations, or those which are produced by the ingress of a low order of organism or fungi—for example, after an injury to the tissues from some traumatism.

Significance of Micro-organisms.—*Micro-organisms*, especially the fungi schizomycetes or bacteria, are the worst enemies of the surgeon, interfering with the normal healing process of a wound and causing the secondary wound diseases. Hallier, Pasteur, Billroth, Klebs, Eberth, and particularly Robert Koch and his followers, have made great advances in the study of micro-organisms. The honour of having established the etiology of parasitic infectious diseases by means of new methods of investigation belongs chiefly to Robert Koch. At the time when Lister established his antiseptic and aseptic methods of operating on the principle that all infection was due to bacteria, which, though not then proved, nevertheless seemed probable, surgery made

the greatest advance in its history. Every inflammatory process in a wound, especially all suppuration, is due principally to the presence of micro-organisms, while the injury itself plays only a subordinate part.

Causes of Acute Suppurative Inflammation—Significance of Bacteria.—The investigations of Ogston, Strauss, etc., prove that chemical irritants, no matter of what kind, do not excite suppurative inflammation, but that the latter can only be caused by micro-organisms. These authorities performed their experiments with the most rigid antiseptic precautions. Strauss, for example, to prevent accidental infection from the wound, made an eschar over the selected area of skin with the Pacquelin, then through this made his incision with a red-hot knife, and introduced the long tip of a glass tube containing the sterilised fluid into the subcutaneous cellular tissue, the upper end of the tube meanwhile being closed with a cotton plug. The glass tip was then broken off beneath the skin, and the fluid was forced out of the tube and under the skin by blowing with the mouth over the cotton plug. After taking away the tube the injured area of skin was again cauterised. After the introduction in this manner of such chemical irritants as sulphuric acid, turpentine, croton oil, mercury, etc., only a serous, sero-fibrinous, or fibrino-diphtheritic inflammation resulted, but never acute suppuration. If acute suppuration did occur, it was always possible to demonstrate the presence of micro-organisms. These authorities experimented on rabbits, in which, to be sure, a suppurative inflammation is seldom caused by chemical irritation.

But it has recently been proved that these statements are incorrect. Orthmann, Grawitz, and De Barry have demonstrated that sterilised chemical substances, such as nitrate of silver, oil of turpentine, liq. ammonii caustici, digitoxin, etc., can produce acute suppuration in the subcutaneous tissue; and according to Scheuerlen and Grawitz, sterilised cultures of various micro-organisms—in other words, products of bacterial metabolism, such as putrescin, cadaverin, penthamethylendiamin, etc.—act in the same way. A similar conclusion has been reached by Krynski, who experimented on dogs and rabbits with the greatest care, partly by Strauss's and partly by Councilman's methods, using germ-free (aseptic) chemical substances, the microbes which cause suppuration and the products of their metabolism. Krynski asserts, in opposition to Strauss and others, but agreeing with Brewing and Dubler, that oil of turpentine or mercury produces in dogs and rabbits a suppuration which is free from bacteria. A one-to-five-per-cent. solution of nitrate of silver excites the formation of pus in dogs, but only an inflammatory œdema in rabbits. Croton oil, bromine, mineral acids (hydrochloric, sulphuric, nitric, and chromic), organic acids (acetic, carbolic, lactic, etc.) do not cause pus. In dogs it is produced by creolin and petroleum. Clean, mechanically acting agents, such as glass splinters, do not excite pus formation. The bacteria of suppuration (the staphylococci and streptococci), according to Krynski, will only excite the formation of pus in tissues which have become pathologically changed, and they will not develop in healthy tissues, but become destroyed, while the bacillus pyogenes fœtidus will excite suppuration even in perfectly healthy tissue. Krynski maintains that the pneumococcus Friedländeri and the micrococcus prodigiosus are not pyogenic; but Grawitz and De Barry have established the latter's pyogenic character in the case of dogs, cats, rabbits, and

rats. Sterilised cultures of the staphylococci and streptococci, or the sterilised solutions of the products of their metabolism, will produce pus, while sterilised cultures of the prodigiosus and decomposition extracts have no such power. Although there can be no doubt as to the possibility of exciting suppuration in the subcutaneous tissue of animals by the experimental introduction of germ-free chemical substances, yet it is just as true that suppuration in man under ordinary circumstances is caused by the presence and activity of micro-organisms, usually of a specific variety—viz., pyogenic cocci.

Immunity against Virulent Staphylococci.—The investigations of Roux, Kronacher and others are of great interest as regards the acquirement of immunity against virulent staphylococci. By the inoculation of sterilised cultures of the staphylococcus pyogenes aureus white mice can be made unsusceptible to cultures containing virulent cocci.

Bouchard, Gley and others have shown that the injection of the soluble products of certain micro-organisms such as the bacillus pyocyaneus has an antiphlogistic effect from paralysis of the vasodilator nerves, which prevents dilatation of the vessels and emigration of the leucocytes.

Leber's Phlogosin—Buchner's Bacterial Protein.—Leber's investigations are extremely interesting.* He showed that the micro-organisms, in virtue of the diffusible products of their metabolism, can excite an inflammatory reaction at a distant part of the body, and from liquids containing staphylococci he isolated a crystallisable body, phlogosin, capable of producing intense inflammatory and necrotic processes. Buchner demonstrated that the protoplasmic contents of the bacterial cells, the so-called bacterial protein, has a similar power of exciting inflammation and suppuration when separated from the bacterial cells—in other words, when these die or become diseased. Buchner has so far isolated this protein from seven kinds of bacteria, and proved its pyogenic action.

Inflammatory Leucocytosis.—After invasion of the blood-vessels with the fungi of suppuration there is an increase in the number of leucocytes in the blood (inflammatory leucocytosis), originating in the spleen, the lymph glands, and bone marrow. According to Limbeck, this is not so much a new formation of leucocytes as a result of the flushing out of the above organs. This inflammatory leucocytosis has an intimate connection with the exudation accompanying inflammation, and with the peptonuria (Leber, Hofmeister, Maixner, etc.).

As to the influence of micro-organisms upon the production of wound diseases, etc., we shall see later (§ 66) that each separate wound disease is caused by a particular and clearly distinguishable micro-organism. A short review of the morphology and general significance of these will be found in § 59.

§ 58. **Symptoms, Diagnosis, and Treatment of Inflammation.**—The symptoms of inflammation—redness, swelling, increased warmth, and pain—are easily explained by the disturbances of circulation which have been described. The redness and increased warmth are due to the

* Fortschritte der Med., 1888, No. 12.

distention of the blood-vessels; the swelling is likewise the result of this, and also of increased exudation. The pain is caused by the pressure of the over-filled vessels and of the exuded fluid upon the sensory nerves. A fifth symptom is the disturbance of function, and is produced by the change in the circulation and the pressure of the exuded fluid upon the motor nerves, and upon those governing secretion, or upon the cells themselves. The separate symptoms naturally vary considerably in intensity, depending upon the severity of the inflammation, and particularly upon its location.

The pain in inflammation depends upon the richness of the sensory nerve supply in the inflamed part, and upon the amount of the exudate, or rather of the pressure which the exudate produces on the sensory nerves. Furthermore, the amount of expansion that the inflamed part is capable of is an important factor. For all these reasons, an acute inflammation located under the fascia, or in the tips of the fingers, under the nails, is particularly painful, while one involving mucous membrane is much less so.

The increased warmth is the result of an increased amount of blood. As Cohnheim has shown, nearly double the normal amount of blood flows through a dog's paw when inflamed. There is an increased amount of warmth brought to the part, but the diminished rapidity of the current causes an increase in the loss of heat by radiation. There has been an erroneous belief that the inflammatory focus was in itself productive of heat, and that the temperature at this point was higher than the general body temperature. But ordinarily it is certain that the temperature of the inflamed spot never exceeds that of the blood, and generally is not as high. Hunter's law still holds true to this day —viz., that the local temperature of an inflamed part cannot rise above that at the source of the circulation, the heart. The redness is usually dependent upon the richness in blood supply of the inflamed tissues. The swelling or inflammatory tumefaction resulting from the exudation which takes place varies, of course, with the anatomical structure of the inflamed region. In general, the exudation takes place in the same way, but it may manifest itself in many different ways, depending upon whether it occurs in firm tissues like bone or cartilage, or in wide-meshed connective tissue, or in a glandular organ, or in a cavity, such as the pleural cavity.

As regards the location of the inflammation, we distinguish between a superficial and a deep or parenchymatous inflammation in the interior of an organ. To the superficial inflammations belong those situated in the superficial portions of the body, in the mucous membranes, or the surfaces of the great serous cavities. In a superficial inflammation the

inflammatory exudate appears superficially, and forms an exudate in the narrow sense, while in a parenchymatous inflammation the exudate is spread out in the tissue in question in the form of a so-called infiltration. For distinguishing the location of the parenchymatous inflammations more exactly—as, for example, those which occur in the glands or muscles—a distinction is made between a parenchymatous inflammation in its narrow sense and an interstitial inflammation, according as the inflammatory process affects more the gland cells, such as those making up the parenchyma of the liver, or the connective-tissue stroma.

The Varying Constitution of the Inflammatory Exudate.—The composition of the exudate is of the greatest importance in determining the character of the inflammation. If the latter belongs to the lower grades of the process, or if, in other words, there is but a slight change in the walls of the vessels, the exudate is serous—that is, there is only a small amount of albumen and formed elements (blood-corpuscles) contained in it. On the other hand, we speak of a fibrinous or croupous inflammation when the exudate is rich in spontaneously coagulating albumen and in white blood-corpuscles. In a fibrinous inflammation the diseased part, such as, for instance, the serous membrane or the inner surface of a joint capsule, becomes covered with a more or less thick layer of soft fibrin, which gives it sometimes a smooth and sometimes a shaggy appearance. The microscopic examination of such a fibrinous pseudo-membrane reveals the presence of an immense number of white blood-corpuscles scattered amongst threads of fibrin and granular matter. This same croupous or fibrinous covering is found on the surfaces of mucous membranes. Between the two main types of serous and fibrinous inflammations there are, of course, a number of intermediate forms which are designated as sero-fibrinous exudates.

Suppurative Exudate.—The third kind of exudate is the suppurative or purulent, consisting of a thick, milky or cream-like, non-coagulable fluid, generally without odour, and briefly designated by the name of pus. Microscopically, this is a colourless fluid containing a vast quantity of cells, "pus-cells," and a few red blood-corpuscles. According to Grawitz, the suppurative inflammation is only a more advanced grade of inflammation, while Weigert, on the other hand, maintains that it represents qualitatively a particular kind. Stricker and Recklinghausen think that suppuration is not exclusively a melting-down process of the tissues without coagulation, produced by means of emigrated leucocytes, but rather that a proliferation of the fixed connective-tissue elements also plays an important part. By the proliferation of the fixed cells a large number of young cells are formed which correspond in appearance to the mononuclear white blood-corpuscles.

Pus is a product composed of emigrated leucocytes and the altered offspring of the connective-tissue cells. Every suppurative inflammation is to be considered as a severe inflammation, and, as we have indicated, it is in the main of an infectious nature—that is, it is the result of an infection by bacteria. But we have seen that sometimes even germ-free chemical substances may produce suppuration (Grawitz, De Barry, Krynski, etc.).

Between the extreme types of purulent and fibrinous inflammation there are also many intermediate gradations of the process which are known as fibrino-purulent inflammations. If the suppurative process is sharply defined in the tissues, there results what is called an abscess; but if the process is more diffuse, it is spoken of as suppurative infiltration. An abscess—i. e., a cavity filled with pus—results from a suppurative infiltration which liquefies and dissolves the affected tissues. A loss of substance in the superficial portions of the body, accompanied by the formation of pus and breaking down of the granulation tissue, constitutes an ulcer. A collection of pus in a cavity is called a purulent effusion, while a purulent secretion from a mucous membrane is called a purulent catarrh.

Hæmorrhagic Exudate.—The fourth kind of exudate is the hæmorrhagic—i. e., the serous, fibrinous, or purulent exudate contains such an amount of red blood-corpuscles that it becomes red in colour. The hæmorrhagic exudate is a symptom of serious alterations in the walls of the capillaries, such as takes place in certain constitutional diseases, or as the result of a systemic infection through bacteria.

Ichorous Exudate.—The decomposed, foul-smelling exudate accompanying putrefaction is designated as ichorous or putrid. It has a grey or greyish-green, brown, or dirty yellow colour.

Croupous or Diphtheritic Inflammation.—The so-called croupous or diphtheritic inflammation, or the croupous or diphtheritic exudate, is the result of the combination of an inflammatory process with another of a different nature. Croupous inflammation of a mucous membrane is characterised by the formation of a skin-like, fibrinous exudate (croupous membrane) clinging to its surface and taking the place of the original epithelial covering which has perished. This croupous membrane consists of a network of fibrin fibres containing leucocytes and the remains of the epithelium. In diphtheria the death of tissue extends deeper, and the process is a combination of necrosis and fibrinous inflammation. The affected portion of the mucous membrane is changed into a peculiar greyish-white, tough mass, which comes away in membrane-like layers (diphtheritic pseudo-membrane), and produces corresponding losses of substance (diphtheritic ulcers). The tissues de-

stroyed by the inflammatory process coagulate in flaky or stringy masses, which signifies serious structural changes involving the blood-vessels and surrounding tissue, with here and there stasis and thrombosis. Cohnheim and Weigert have given to this form of localised tissue death the name of coagulation necrosis (Neumann's fibrinoid degeneration). Weigert's investigations show that coagulation necrosis is a death by coagulation of the tissue or cells in a necrotic area through which a small amount of lymph flows. The lymph, with its fibrinogen, penetrates the cells and coagulates with the fibrino-plastin within the cells. Coagulation necrosis is a frequent accompaniment of inflammatory processes, of embolic infarcts, and of the so-called waxy degeneration of muscles.

Extension of an Inflammation.—The inflammatory process spreads by infiltration of the connective-tissue spaces, the muscular sheaths, and the vascular channels with the inflammatory exudate—in other words, from a circumscribed spot of suppuration (abscess) there may develop a spreading cellulitis. The inflammation also spreads through the lymph spaces, the main lymphatics, and the blood-vessels. When the exciting cause of the inflammation gets into the circulatory system, the original local disturbance becomes a general systemic disease involving the whole organism. The poison—so to designate briefly the noxious element—passes through the lymph channels to the nearest lymphatic glands, exciting there also inflammation, and finally suppuration. These diseased glands then become a fresh source of inflammation, which in this manner spreads farther and farther through the body and progressively affects more of its organs. Such a metastatic inflammatory and suppurative process will be again referred to under the heading of pyæmia, by which we mean a poisoning of the blood by the microbes of suppuration and the products of their metabolism. By the spreading of the micro-organisms and the products of their metabolism throughout the circulation, and the production of circumscribed foci of inflammation in different organs, a general systemic infection accompanied by fever results (see § 62, Fever). We shall learn later how prominently the fungi are concerned in the extension of the inflammation and in the occurrence of the systemic infection. Clinical observations and experiments on animals seem to show that local metastatic foci of suppuration are particularly liable to occur when there exists a general weakness or impairment of vitality of the whole organism (Rinne). The soil for the lodgment of the micro-organisms is made ready for them in advance by the products of their metabolism which get into the circulating blood.

Duration of the Inflammation.—According as the inflammation lasts

a shorter or longer time it is spoken of as acute or chronic. The manifestations of an acute inflammation have been sufficiently described above. The acute inflammation often becomes a chronic one, or the latter begins from the first as such. The transition or intermediate types between an acute and chronic inflammation are known as subacute inflammations. Tubercular and syphilitic inflammations are the most important forms of the chronic class. The true type of chronic inflammation is the productive or adhesive inflammation, which leads to new formation of tissue, to adhesions and thickenings of every description, depending upon the anatomical structure of the affected organ, such as a joint, bone, periosteum, or connective tissue. We shall describe in their proper place the special symptoms of inflammations involving the different organs.

Origin of the Pus-corpuscles.—The so-called pus-corpuscles which are found in the inflammatory effusion are made up, in part at least, of the white blood-corpuscles which have wandered out from the interior of the vessels. Whether all the pus-corpuscles are emigrated blood-cells, or whether pus-cells may originate otherwise—as, for instance, from the fixed tissue cells—or whether pus-cells may multiply by fission or division, are all questions to which various answers have been given. Some have considered it impossible that the enormous number of pus-corpuscles found in a large inflammatory process, like a phlegmon or a large granulating wound, should all be derived from the blood. Cohnheim was right in directing attention to the fact that the veins and capillaries contain comparatively large numbers of white blood-corpuscles, and that the number of these white cells is much increased during inflammatory diseases. The white blood-corpuscles which go to form pus-cells are constantly replaced by an increased activity of the spleen and lymphatic glands. Böttcher, Stricker and his followers, Recklinghausen, Grawitz and others differ from Cohnheim in his view that the blood is the sole source of the pus-cells, and affirm that the latter originate in far greater proportion from the fixed tissue cells. These authors believe that the cellular elements of pus consist partly of emigrated leucocytes and partly of the offspring of the fixed connective-tissue cells. Grawitz affirms that the stroma or fibrous portion of the tissues takes on a cellular change and becomes a third source of the pus-corpuscles. Recklinghausen has demonstrated that pus-cells, if kept in a warm and moist medium while being examined, will change their form and go through the same amœboid movements as the white blood-cells.

Number of Pus-cells in Pus.—Chelchowski determined the number of pus-corpuscles by means of Mallassey-Verick's apparatus in twenty different cases of suppuration. For diluting the pus, he employed a weak solution of common salt or Toisson's fluid (methylviolet). The number of pus-cells in one cubic millimetre of pus, according to Chelchowski, varied between four hundred thousand and one million six hundred thousand. The exudate contained from ten to fifteen times more leucocytes than the transudate.* The

* In the sense of a passive effusion, as in cardiac dropsy.

suppurative character of a fluid, drawn off by aspiration, can only be recognised macroscopically when it contains at least from forty to sixty thousand pus-cells to the cubic millimetre, and consequently it is very possible for a comparatively large amount of pus to be present in a fluid without its being noticed.

Composition of Pus.—Pus consists of the above-mentioned cellular elements, which are called pus-corpuscles, and, in addition, of pus serum. If pus is allowed to stand for a time in a test tube, it separates into two layers the upper bright yellow layer being the pus serum, and the lower forming a thick deposit made up principally of pus-corpuscles. The pus serum corresponds to the plasma of the blood which is its source, but often differs from it chemically very materially. There are ten to sixteen per cent. of solid elements in pus, and five to six per cent. of ash. The gases consist of nitrogen and carbonic acid ; ordinarily there is no oxygen or hydrogen. There is generally a somewhat greater amount of sodium and potassium than in blood serum. The albuminous substances in pus consist chiefly of paraglobulin, albuminate of potassium, serum albumen, myosin, leucin, and tyrosin. The formed constituents, in addition to the pus-corpuscles, include micro-organisms, and often red blood-cells, fibrin, fat droplets, fat and cholesterin crystals, particles of necrotic tissue, etc. Pus which contains fungi usually does not coagulate, although large numbers of leucocytes may be present. This is due to the fact that there is no fibrinogen in the pus, or rather that the micro-organisms change the fibrinogen in the exuded plasma into peptone.

Growth of Bacteria in Germ-free Pus.—According to Eichel, germ-free pus contains a substance which is deleterious for many kinds of bacteria, and small quantities of the staphylococcus pyogenes aureus and the anthrax bacillus will perish after about five days, but the streptococci are not harmed. By the addition of putrefactive bacteria or the products of their metabolism this deleterious property is increased. The reaction of pus which has recently been taken from the body is alkaline, but it becomes acid after long exposure to the air.

Coloured Pus.—Green or blue pus is sometimes found instead of the usual creamy, more or less yellow-coloured variety. This discolouration is usually brought about by the presence of the bacillus pyocyaneus (see pages 313, 314). O. Grube and Ferchmin have seen fourteen cases of bright red pus. The cinnabar colour is due to a specific bacillus (see page 314). Orange-coloured pus occurs as the result of the admixture with crystals of hæmatoidin.

Outcome of an Inflammation.—In considering the outcome of an inflammation, the secondary conditions that follow must be distinguished from the purely local processes at the seat of the inflammation. As regards the system at large, the main purpose of inflammation is to do away with the causes which give rise to the inflammation, accomplishing this by increased metabolism, rapidity of circulation, and transudation. The processes which take place in an inflammation combat its causes in an efficient way, and try to make reparation for the damaging effects that it produces (Leber, Arnold). In many cases the inflamma-

tion is not capable of removing the causation of the disease. Death may occur at any stage of the inflammation, but especially when the inflammatory process is at its height, as a result of a general systemic infection with fever, due to the primary local inflammation. We shall learn in § 62 about the significance of fever and its dangers for the organism. From a prognostic standpoint, the location of the inflammation is of the greatest importance. A subcutaneous abscess is by no means as dangerous to life as a very minute collection of pus in the bones of the skull, the meninges, or in the brain, the medulla oblongata, etc. The age and constitution of the patient is likewise an important factor.

If we take a purely local view of the outcome of an inflammation, the worst that can occur is gangrene or necrosis—i. e., death of the affected tissues. In its various gradations this is a very frequent result of an inflammation, and is due either to complete stasis in the vessels, followed by coagulation of the blood which they contain, or to pressure of the exudate on the surrounding tissue. Furthermore, in a localised death of tissue, constitutional conditions, such as diabetes or old age, play a very important part. We shall return to the discussion of localised death of tissue (gangrene, necrosis, or mortification) in another chapter. It will only be stated now, that in general the extent of the inflammatory necrosis varies greatly, depending upon the intensity and extent of the inflammation. We shall see that the influence of micro-organisms, such as single groups of bacteria, is a prominent factor in the production of gangrene. The capability on the part of the tissues, and especially of the vessels, of withstanding gangrene varies greatly with the portion of the body which is affected and with the individual. The most favourable outcome of an inflammation is a complete *restitutio ad integrum*—a perfect restoration to the original condition—which of course is most frequently observed after an inflammation of a mild type in which the exudate has been scanty and chiefly serous. The disappearance of the phenomena of inflammation begins as soon as the circulating blood has restored the walls of the blood-vessels to their normal condition, and when this has taken place the exudation ceases. The fluid portion of the exudate is absorbed by the lymph vessels, likewise the white blood-corpuscles and fibrin, after they have in part undergone a fatty degeneration. The red blood-cells lose their colouring matter, and gradually become disintegrated. The fixed tissue cells which have been damaged by the inflammatory irritation recover after the restoration of their normal nutrition, and by degrees a complete restitution takes place. Sometimes, however, after absorption of the fluid the formed or solid elements of the exudate remain

behind as a light yellow, caseous mass, which, by a reactive inflammation, becomes encapsulated as a cheesy nodule, like a foreign body. Under such conditions complete absorption often does not occur, and finally a deposition of salts of lime takes place, forming a firm, calcareous concretion.

If the inflammatory process is more severe, and if there is localised death of tissue, the absorption of the exudate and the necrotic soft parts takes place in a similar manner—i. e., by absorption of the fluid and fatty emulsion of the solid elements. Small portions and granules of tissue, in case they are not taken up by the lymph channels, are seized by the cells which have wandered out of the vessels, and which in this way become granular cells. If, as the result of an inflammation, a portion of bone has become necrotic, the dead piece of bone or sequestrum is separated from the living bone by a suppurating line of demarcation (see § 106). The pus formed during an inflammatory process near the surface of the body may break through spontaneously, or be removed artificially by operative measures, such as incision, etc.

There is the danger in all infectious inflammations, or those cases of suppuration which are due to micro-organisms, that the inflammation may become the starting-point for a general infection. Therefore, whenever it is possible, operative measures should be undertaken at an early period to provide a way of escape for the exudate, for otherwise the inflammation and suppuration may spread, resulting in an extensive infiltration or phlegmon, which may break through into an important organ, such as a joint, the cranial cavity, abdominal cavity, etc. Moreover, the micro-organisms that cause the inflammation are scattered about by the lymph- and blood-vessels. It must always be borne in mind that products are constantly being formed in an infectious inflammation which are capable of producing further inflammation in the surrounding parts and in widely separated organs. The bacteria, and the products of metabolism and decomposition which they cause, are here again the causes of the secondary inflammatory processes. As a result, then, of infectious inflammations, bacteria may be deposited in large numbers in different internal organs, causing secondary so-called metastatic abscesses.

Scar Formation.—If a defect or loss of substance results from a severe inflammation with necrosis, this is remedied to a greater or less extent by a new production of connective tissue, which is then called cicatricial tissue. Scar formation is to be looked upon as an inflammatory process which is productive in character. A germinal or granulation tissue, as it is called, develops, consisting only of round cells with a very small amount of interstitial substance; this granulation tis-

sue then gradually changes into fibrous connective tissue, which makes up the cicatrix. I used to believe, as Cohnheim did, that the new-formed connective tissue, the granulation and cicatricial tissue, was chiefly derived from the emigrated leucocytes, which increased in size when the new blood-vessels developed amongst them and became large, irregular-shaped cells (fibroblasts). But some recent investigations have made me conclude that the leucocytes at the inflammatory focus are unfit for making new connective tissue and healing up the wound, and I am now convinced that they gradually disappear, partly by wandering into the lymphatic vessels and being carried off in the lymph current, and partly by wandering into other localities and disintegrating and being taken up by the fixed cells of the part (Baumgarten, Zahn, Marchand, etc.). Ziegler has also expressed the same view. The newly formed connective tissue, therefore, is in reality produced by a growth of the fixed connective-tissue cells (Baumgarten, Marchand, etc.). Marchand has proposed to designate the leucocytes originating from the blood and lymphatics as exudation cells, in contradistinction to the granulation or true formative cells which are derived from the tissues. The formative cells get their nourishment from the protoplasm of the leucocytes, as I have mentioned above. Sherrington, Ballance, Shattock and others maintain that the plasma cells are the ones chiefly concerned in the formation of cicatricial tissue (see also § 61).

Regeneration of the Tissues.—Simultaneously with the formation of the granulation or cicatricial tissue there is a proliferation of the fixed (specific) cells in the neighbourhood for the purpose of restoring the cells that make up the particular organ. Epithelium gives rise to epithelium; muscle cells form muscular fibres, though in a very limited amount; periosteal and medullary cells make bone, etc. The power of regeneration possessed by the different tissues varies very greatly, as we shall see. The skinning over or covering of a loss of substance in the skin with epidermis is brought about by the cells of the rete Malpighii and sebaceous glands. Reference is made to § 61 for the description of the various phenomena in scar formation and regeneration in the different tissues (microscopic phenomena in the healing of a wound), and to §§ 87 and 88, (Injuries of Soft Parts). For the process of healing of fractures see § 101.

The healing of a Foreign Body into a Wound.—If the inflammation is caused by the entrance into the tissues of a solid foreign body, the latter may completely heal into the tissues, as we shall often have the opportunity of observing; and this will occur the more readily the more free the body is from dirt, dust, bacteria, products of decomposition, etc. We know that silk sutures, silver wire, bullets, etc., heal up in a wound in this way without giv-

ing rise to any reaction. Foreign bodies which have thus become enclosed often change their location later on, and in their wanderings may make their appearance beneath the skin in another portion of the body. Large, soft foreign bodies are completely absorbed in the way described above. I implanted, under antiseptic precautions, large fresh pieces of liver, spleen, lung, and even entire kidneys of rabbits, in the peritoneal cavities of other rabbits, and found that they became absorbed without producing peritonitis. I also used similar specimens which had been hardened in absolute alcohol, and with the same results. The portions of tissue were invaded by vast numbers of wandering cells and slowly liquefied.

Hallwachs, Rosenberger, Salzer and others have recently studied the subject of the encapsulation of foreign bodies, and Salzer says that those which are smooth and solid become enclosed in a delicate connective-tissue capsule, while the porous, fibrous, rough foreign bodies are most apt to heal into the scar tissue with the formation of very thick layers of connective tissue.

Diagnosis of Inflammation.—In the *diagnosis* of *inflammation*—i. e., of the four above-described cardinal symptoms, redness, swelling, heat, and pain—we make special use of inspection and palpation of the affected part in case it can be seen and touched. If the inflammation is located on the outer surface of the body the diagnosis is simple, but it is more difficult if the inflammation is situated more deeply. By palpation of the inflamed tissues we attempt to determine whether the inflammatory focus contains pus—i. e., whether it "fluctuates" or not. Every fluid, and consequently pus or serum, contained in a cavity having yielding, elastic walls will give fluctuation or a wave movement when the fluid in this cavity is set in motion by intermittent pressure with the index or middle finger. The detection of fluctuation is of the greatest practical importance. If the pus is contained within firm, unyielding walls, such as bone, or in deeply situated tissue with thickened rigid walls, fluctuation cannot be made out. Furthermore, it must not be confused with the pseudo-fluctuation manifested upon palpation of soft elastic parts; but a little experience will soon teach the distinction between the fluctuation of an elastic cavity filled with fluid and the pseudo-fluctuation of soft elastic tissues such as the muscles of the thenar eminence, soft fatty tumours, etc. Puncture with a hypodermic syringe is an exceedingly useful diagnostic measure for determining the nature of the contents of an inflammatory focus (see page 71).

We also employ the sense of hearing in the diagnosis of an inflammation by noting, for example, whether any friction sound is produced by the rubbing together of two opposed inflamed surfaces. Hueter has constructed instruments analogous to the stethoscope used in the diagnosis of diseases of the thoracic viscera; they are a dermatophon,

an osteophon, and a myophon, for the diagnosis of surgical diseases of the skin, bones, and muscles respectively, and they consist of an elastic tube fitted to an ear-piece. We shall refer to this apparatus in diseases of bone, but it may be said here that hitherto it has not been brought into general use.

The febrile disturbance accompanying an inflammation is determined by accurate measurement of the body heat by means of a thermometer placed in the axilla, or, better, in the rectum (see § 62, Fever).

Amongst other aids to diagnosis I should mention the probe, which is used to ascertain the direction and length of a fistulous tract, or the presence of a foreign body. There are also instruments designed for special organs, such as the urethra, bladder, stomach, etc., and a great number of contrivances for inspection of the nose, larynx, bladder, eye, etc.

These general remarks will be sufficient until we return to the diagnosis of inflammations of the separate parts of the body.

Treatment of Inflammation.—At present we can only deal briefly with the *treatment* of *inflammation*, as we shall have to come back to the subject in detail for each separate part of the body. From a prophylactic standpoint it is best to treat every injury, no matter how trifling it may be, on antiseptic principles, after the manner described in a former chapter. In general, the treatment of an acute inflammation consists in the use of suitable antiphlogistic measures, particularly the proper position of the inflamed part, such as elevation in the case of an extremity, in the application of ice, and in the prompt evacuation of the pus or infiltrating exudate by incision.

Blood-letting by leeches, cupping, and scarification used to be much in vogue for diminishing the amount of blood contained in an inflamed portion of the body, but now this practice has very properly been given up. The counter-irritation method of treatment by cutaneous irritants, such as the moxa, issue, red-hot iron, painting with tincture of iodine, and the application of vesicants, is also old-fashioned. It would require too much space to give the outlines of treatment for inflammation according to the location and causes of the latter, and it can be done more satisfactorily in the discussion of the treatment of inflammations of the separate organs. The treatment of the general febrile disturbance due to inflammation will be considered in the treatment of fever (§ 62).

§ 59. **Morphology and General Significance of Micro-organisms.**—By *micro-organisms* or *microbes* is understood a class of minute living organisms which belong to the lowest forms of plant life or stand on the border line between plants and animals. The majority of the mi-

cro-organisms have a diameter of only about one micromillimetre or less. They multiply with extreme rapidity, and are able to live in widely differing degrees of temperature, some in acid and others in alkaline solutions of simple compounds (with the exception of carbon dioxide), as well as of more complex nourishing substances.

The micro-organisms play a very important part in the economy of nature. They excite fermentation and decomposition, and are parasites in living plants, animals, and man, causing in some cases disease and death. By fermentation and decomposition the micro-organisms disintegrate considerable amounts of organic material in a short period of time with the evolution of gas. The change of sugar into lactic acid (sour milk), the lactic into butyric acid, and alcohol into acetic acid, are all processes of fermentation caused by micro-organisms. We make use of micro-organisms in the preparation of many alimentary substances, such as bread, cheese, beer, wine, etc., while on the other hand, as a result of the fermentative and putrefactive action of these low orders of organisms, our food may be rendered unfit to eat.

Micro-organisms also produce poisonous matters (ptomaines, toxines) which are dangerous to the health and life of man. Numerous acute and chronic inflammations, particularly the surgical diseases of wounds, are due to the presence of micro-organisms.

Evidence of the Bacterial Origin of many Infectious Diseases, especially the Diseases of Wounds.—Under normal conditions we find no micro-organisms in the blood and internal organs of healthy human beings and animals; this has been proved beyond a doubt by Meissner and many other investigators. On the other hand, we observe in the various infectious diseases, particularly the surgical-wound diseases, certain micro-organisms in the blood and internal organs, and we know that every infectious disease is due to some specific, plainly distinguished class of micro-organism. These gain access to the body from without by means of the inspired air, the food, water, or by contact with the surface of the body, especially if there is an interruption of continuity in the skin or mucous membranes. The striking results obtained by antisepsis and the aseptic method of operating and treating wounds demonstrate that the infectious-wound diseases are caused by the entrance of micro-organisms into the wound from without. If we perform an operation, taking every precaution not to introduce microbes by our hands or instruments, or from the patient's own skin, into the wound, or, briefly, if we operate aseptically, as we have learned in a previous chapter, with everything germ-free and sterile, and then dress the wound with germ-free (sterilised) materials, such a wound will invariably heal without inflammation and suppuration *per primam intentionem*, or, in other words, by immediate agglutination of its borders, and without giving rise to fever. If there is a transgression of the rules of asepsis or antisepsis in performing an operation or treating a wound, and if micro-organisms get into the wound, inflammation and suppuration and other wound diseases, accompanied by a

corresponding febrile disturbance, will result. If an infected wound is treated with disinfecting substances, such as bichloride (1 to 1,000 – 5,000) or three-per-cent. carbolic solutions, the micro-organisms are prevented from further development and the existing inflammation or suppuration is modified or checked, provided it has not already become too far advanced and no general systemic poisoning has taken place. A further proof of the microbic origin of the infectious diseases is furnished by the successful results of transmission from animal to animal. Cultures of a particular kind of bacteria which had caused a certain infectious disease, were introduced into the body of an animal and here produced the same disease, and the same kind of bacteria could be isolated from the diseased tissues. The micro-organisms damage the human organism in a double manner—viz., by the formation of the poisonous products of their metabolism, and by multiplying very rapidly and invading new portions of tissue.

The Different Kinds of Micro-organisms.—We recognise four large classes of micro-organisms: I. The fungi or moulds. II. The sprouting or yeast fungi (saccharomycetes, blastomycetes). III. The fission fungi, bacteria (schizomycetes). IV. Mycetozoa and protozoa.

I. **Fungi.**—Moulds form the well-known green, yellow, whitish, or black skin-like covering found upon all sorts of dead organic substances. They usually consist of two functionally distinct parts, the mycelium and the germinal hypha or zygospore. The mycelium consists of branching, usually jointed threads, which anastomose with one another and proliferate in the nutrient substrata. The zygospores spring from the mycelium and produce and carry on their ends the seeds or spores (Fig. 221). The latter are round or elongated cells generally having a dense enveloping membrane, and after separation from the zygospore are capable of forming another fungus with its zygospore. The spores can retain their vitality in a dry state for from two to ten years. Numerous species of fungi are distinguished by the manner in which the spores form upon the zygospores. Occasionally the spores undergo segmentation by transverse division of the terminal cells at the extremity of the zygospore (conidia). In other fungi the terminal cell develops into the so-called sporangium or ascus, in the interior of which the spores form by division of the plasma (ascospores). In still others two zygospores grow one within the other, and the so-called oöspores develop at the point of junction of the two spore carriers. The same fungus will occasionally form its spores in several different ways, depending upon the conditions in which it exists (conidia and ascospores).

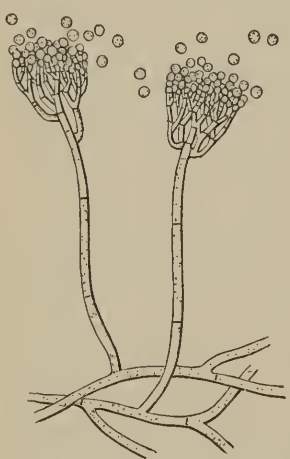


Fig. 221.—Penicillium glaucum, × 500.

Conditions suitable for the Life of the Fungi.—The fungi are found upon

every description of dead substance, and upon substances which contain a relatively small amount of water and have an acid reaction, thus differing from the bacteria. For making pure cultures of fungi, the best materials are boiled potatoes, bread pulp, and gelatine, or the agar mixture rendered acid by the addition of two to five per cent. of tartaric acid, to prevent bacteria from taking root along with the fungi. The temperature is an important matter, some species thriving best at +15° C. (59° F.), and another at +40° C. (104° F.). The spores will only form when there is plenty of air, oxygen being essential, and consequently most of the fungi will not multiply in the interior of animal tissues nor in blood; they ordinarily exist only upon such portions of the body as are freely exposed to the atmospheric air.

Penicillium.—The commonest fungus is the penicillium glaucum (Fig. 221). It grows in distilled water and many kinds of medicine, best at a temperature of from 15° to 20° C. (59° to 68° F.), while at 38° C. (101° F.) it gradually dies. The mycelium has a flocculent, white appearance, turning green after the formation of the spores. The latter do not grow when introduced into warm-blooded animals by injection into the blood or by inhalation, and they may remain for weeks in the liver and spleen.

Oidium.—There are numerous species of the oidium which flourish partly upon a dead substratum and partly (like mildew) upon living plants. They are regularly present upon sour milk. Mycelium and spores are white. They thrive best at a temperature between 19° to 30° C. (50° to 86° F.). They have plain, upright zygospores, bearing chains of cylindrical spores. Fungi of the oidium class are found in favus, pityriasis versicolor, and herpes tonsurans.

Monilia.—The monilia is distinguished from the oidium by its zygospore, which takes a bushy-shaped, branching form as it springs from the mycelium. It causes thrush.

Mucor.—There are many species of mucor, some of which thrive best at a temperature of 37° C. (98·6° F.), and cause death in rabbits when their spores are injected into the blood-vessels in large amounts. There are then found in the internal organs, particularly the kidney, a great number of small fungi which do not fructify. They are chiefly found in man, in the external auditory meatus. The spores are developed in sporangia.

Aspergillus.—They generally germinate like the conidia, less frequently having ascospores. The aspergillus glaucus is greenish yellow, is harmless as regards warm-blooded animals, and is generally found in damp walls, fruits which have been stored away, etc. The aspergillus niger, fumigatus, flavescens, and subfuscus are pathogenic, and the maximum temperature compatible with their existence is about 37° C. (98·6° F.). The injection of large numbers of the spores will kill rabbits, numerous foci of the fungus being found in the heart, liver, and kidneys. Spores of aspergillus fumigatus exist chiefly in the air-passages of birds. In man, colonies of this species of aspergillus have been observed in the bronchi, lungs, external auditory meatus, upon the cornea, etc.

Actinomyces.—The actinomyces or ray fungus is found in cattle and man chiefly in the tongue, jaw, and lungs, where it causes abscess and suppurating growths. Harz, De Barry and others placed the actinomyces amongst the fungi, but the recent investigations of Israel, Ponfick and Bostroem seem to prove it to be a branched form of cladothrix (see § 86, Actinomycosis).

Pathological Importance of the Fungi in Man.—The pathological bearing of the fungi upon man, as ascertained by experimental and clinical observations, is briefly as follows: It is well known that the fungi occasionally find lodgement in the epithelium of the skin and mucous membranes, and in the former situation give rise to favus, herpes tonsurans, and pityriasis versicolor, and in the latter to thrush. E. Wagner has noticed that the threads of the thrush fungus penetrate into the blood-vessels of the mucous membrane; and Zenker found in the brain of a child affected with thrush multiple abscesses with sprouting spores of the thrush fungus in their centres. Fungi are capable of growing in the tissues of warm-blooded animals through which blood is circulating. Grohé at first denied this, but it was subsequently affirmed by Grawitz, though the fungus has to undergo an "accommodative cultivation" before it can live in the alkaline blood at a temperature of 39° C. (102·2° F.). Experiments made by Koch and others have demonstrated that there are pathogenic fungi which are capable of development in the tissues of warm-blooded animals without having undergone any previous particular kind of cultivation, while the non-pathogenic fungi never possess this power even though they have first been subjected to cultivation. The non-pathogenic fungi include the penicillium glaucum, the aspergillus glaucus and niger, the mucor mucedo, and stolonifer. The species which are certainly pathogenic include: 1. The aspergillus fumigatus, distinguished from the aspergillus glaucus by its very small size and that of its spores, its dirty green colour, the manner of its growth, its poor development at ordinary temperatures, and the very rapid growth manifested in temperatures equal to blood heat. The aspergillus fumigatus is present in bread, and is readily cultivated on dough kept at a temperature of 39° to 40° C. (102·2° to 104° F.), as a dark-green fungous covering. 2. The aspergillus flavescens is similar to the aspergillus fumigatus, and is characterised by its yellowish-green colour. 3. The mucor rhizopodo-formis is distinguished from the non-pathogenic mucor (Rhizopus) by the greyish-brown colour of its mycelium, the large size of its individual parts, its small, round, colourless spores, and by the egg-shaped columella dilated at its top. 4. The mucor corymbifer is known by the snow-white colour of its mycelium and its characteristic form.

Internal fungous diseases arising spontaneously in, for instance, the lungs and intestinal tract, are seldom seen in man, as the pathogenic fungi (of the aspergillus and mucor varieties) will only thrive at a high temperature, and consequently are not very plentiful in the air, water, or alimentary substances. Furthermore, the fungi are only pathogenic when they exist in great numbers, while the system is capable of overcoming a few of them without itself suffering harm (Grawitz), and their increase by means of spores does not take place in living tissue. Fungous diseases are most easily excited by intravenous injection of the organisms. Lichtheim's mucor injections proved fatal in rabbits in every case, while dogs were not affected at all. Morse, Kaufmann and Schulz caused animals to inhale and swallow large amounts of pathogenic fungi without producing any ill effect; Lichtheim noted only a scanty and stunted vegetation in the lungs after inhalation. In man there is occasionally observed a pneumomycosis aspergillina (aspergillus fumigatus) and a pneumomycosis mucorina, secondary to already existing pulmonary disease. There is also a keratomycosis aspergillina, a corneal

lesion, and an aspergillus mycosis of the external auditory meatus (oto- or myringo-mycosis aspergillina), produced by the aspergillus fumigatus, flavescens, and nigrescens. According to Carter, the Madura foot, a disease like elephantiasis, endemic in India, and characterised by the formation of warty lumps, suppurating in their interior and terminating in death after about a year, is caused by a fungus, the chionyphe Carteri, related to the mucor stolonifer; but other investigators have disputed this. As a general thing, man may be said to be immune to the pathogenic fungi hitherto identified; but under conditions not yet understood these fungi may take on a fatal activity, as exemplified by the above-mentioned case of Zenker's, and a recently described and interesting case of Paltauf, in which a man died in coma after what appeared to be an enteritis and peritonitis. In the brain, lungs, and intestine were found inflammatory foci, or abscesses, containing mycelia of the mucor variety (mucor corymbifer). It is by no means impossible that still other new forms of fungous disease may be found to have their existence in man. All the facts which are known as regards the pathogenic fungi are of great surgical interest. The fungi play a very important part in the production of diseases in plants and low orders of animal life, such as the grape disease, the potato disease, the "rot" of grain, the muscardine disease of silkworms, and various diseases in insects, etc.

II. **The Yeast Fungi** (*Blastomycetes*).—The yeast fungi (Fig. 222) are round, oval cells of different sizes, varying from two to fifteen micromillimetres in diameter, having a thin enveloping membrane and granular protoplasm, in which there are frequently vacuoles (Fig. 222). They multiply by budding or putting forth daughter cells, which finally become separated from the mother cells by a partition, and either remain in contact with their parent cell for a considerable time, forming more or less long chains, or they become entirely separated. Many, though not all of the yeast fungi produce in solutions of sugar alcoholic fermentation, changing grape sugar into carbonic acid and alcohol. The true yeast-fungi which cause fermentation (saccharomycetes) must be distinguished from the other fungi of the same class. The mycelia of the typical mould fungus—for instance, the mucor species—can form chains and can cause alcoholic fermentation in a solution of sugar. Macroscopically the yeast plant forms a white cloudy sediment in a fermenting fluid, or a white scum over the surface of alcoholic fluids which are spoiling. In solid nutritive media (gelatine) the yeast fungus makes spores by developing free cells within the enlarged mother cell (ascospores). Beer-wort and decoctions of malt or prunes, to which sugar is afterwards added, form the best culture media, but they must be mixed with one per cent. of tartaric acid to keep out the bacteria.

Fig. 222. — Yeast fungus. Saccharomyces cerrevisiæ. Vacuoles are present in some of the larger cells.

The pathological interest of the yeast fungi is limited; they occasionally give rise to fermentation in the stomach. Some writers think that thrush is caused by a variety of the yeast fungus (mycoderma).

III. **The Bacteria** (*Schizomycetes*).—The bacteria (from τὸ βακτήριον, a small rod, from the rod shape which many of them have) are very

small, simple cells of a low order of vegetable life related to the lower orders of algæ. They are divided into several distinct classes, according to their shape and the effects which they produce. Nevertheless, under altered conditions in their life the bacteria of one class change their shape and function to a greater or less degree. There are chiefly to be distinguished—1. The micrococci. 2. The bacilli. 3. The spirilli.

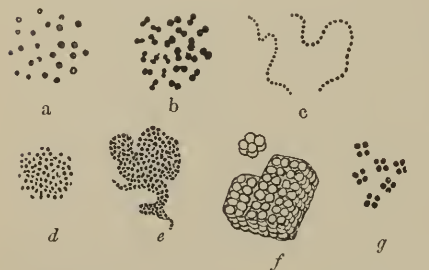


Fig. 223.—Different varieties of cocci: *a*, Smaller and larger cocci; *b*, diplococci; *c*, chain coccus (streptococcus); *d e*, clusters of cocci in the form of a bunch of grapes (staphylococci); *f*, sarcina (packet coccus); *g*, micrococcus tetragonus.

1. *The Spherical Bacterium* (*Micrococcus or Coccus*).—The micrococci are small, round or oval cells, which by division or fission always produce in turn the same round cells. The micrococci exist either as isolated spherules (Fig. 223, *a*), or they remain in pairs after dividing (diplococcus, Fig. 223, *b*), or the spherules cling together in chains (streptococcus, Fig. 223, *c*). In other instances they form irregular groups (staphylococcus, Fig. 223, *d*, *e*). Large groups or colonies bound together by some sticky material such as mucus are called zoögloa. Sometimes the micrococci develop in groups of four (merismopædia, merista, Fig. 223, *g*), or they are joined together in cubes (sarcina, Fig. 223, *f*). The sarcina is found in the stomach of man, as sarcina ventriculi, when decomposition of the gastric juice is present.

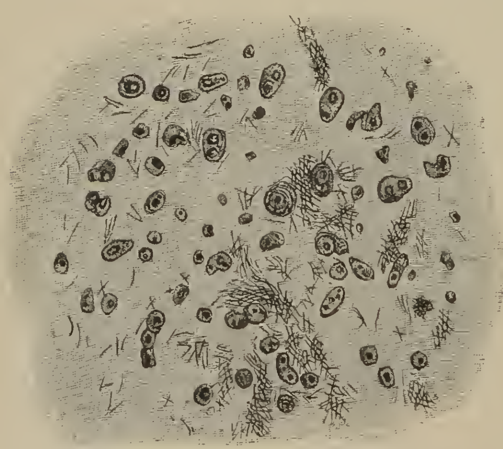


Fig. 224.—Tubercle bacilli (lung), ×700 (Koch).

2. *Rod-shaped Bacteria* (*the Bacillus*).—In all bacilli the longitudinal diameter exceeds the transverse, and their size varies very greatly (Figs. 224, 225, 226). The bacilli divide transversely, and, like the cocci or the streptococci, they form longer or shorter threads by remaining attached to one another after division (leptothrix, Fig. 226). These threads, in

contrast to the mould fungi, never become branched, though several threads lying next each other may give the appearance of branches. Particularly the anthrax bacilli (Fig. 226) and the bacilli of malignant œdema have the form of long threads. Many bacilli possess an enlargement at their centre or end, and such spindle-shaped or tadpole-formed rods are known as clastridia.

Fig. 225.—Blood from a mouse with anthrax, dried on the cover-glass and stained with methyl violet. Red blood corpuscles and anthrax bacilli, × 700 (Koch).

Fig. 226.—Anthrax bacilli joined together in the form of threads from a three hours' old culture of the blood of a guinea-pig in humor aqueus, × 650 (Koch).

3. *The Spiral-shaped Rod Bacillus* (*Spirillum*).—The spirilla (Fig. 227) have the appearance of spirally twisted threads or fragments of cork-screws. The bacterium which has the twist but slightly marked is known as a vibrio (Fig. 228).

Under each of the separate classes of bacteria there are many varieties and species which are of great importance from a diagnostic standpoint.

Thus there are small or large, oval or lancet-shaped cocci, also slender and broad bacilli, etc. Within one species differences occur depending upon the conditions of nourishment or age.

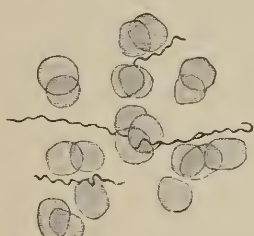


Fig. 227.—Spirochætæ Obermeieri (spirillum of relapsing fever), × 700.

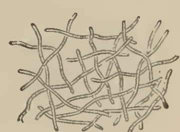


Fig. 228.—Group of vibrio serpens, × 650 (Flügge).

The Structure and Reproduction of Bacteria.—The bacteria, like other vegetable cells, consist of an inner portion surrounded by an enveloping membrane. Their interior is made up of albuminoid matter, fats, salts, and water, while the enveloping membrane is probably allied to one of the cellulose bodies belonging to the hydrocarbon compounds. C. Fränkel and others consider it doubtful whether or not a nucleus exists within the protoplasmic contents of these cells.

The bacteria are often surrounded by a gelatinous enveloping substance, which facilitates the formation of the above-mentioned bands. It can in some cases be made visible by the usual staining materials, but in others a special treatment is necessary with iodine.

Movements of Bacteria.—Many bacilli and spirilli are capable of active movement, and of moving from one spot to another. The micrococci do not possess the power of locomotion, but are seen to have only a tremulous molecular "Brownian" movement; but Löffler and Mendoza have recently discovered two species of micrococci which do have the power of motion. The locomotion of the bacilli and spirilla which are capable of motion is brought about by peculiar organs called cilia or flagella. Löffler has recently, by means of a particular method of staining, demonstrated these flagella in a great many of the important pathogenic bacteria. The flagellum is found either at one end only or at both ends of the organism, and is often very long (Fig. 229). Other bacteria, such as the spirillum undula, possess at each end not a single flagellum, but a whole bunch of fine filaments all curved in the same manner. R. Pfeiffer, with the assistance of Löffler's staining process, has demonstrated that many bacteria, such as the typhoid bacilli, have their entire periphery studded with fine cilia, causing them to resemble a centipede or a spider (Fig. 230).

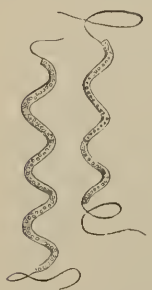


Fig. 229.—Spirillum volutans, each with a flagellum on either end.

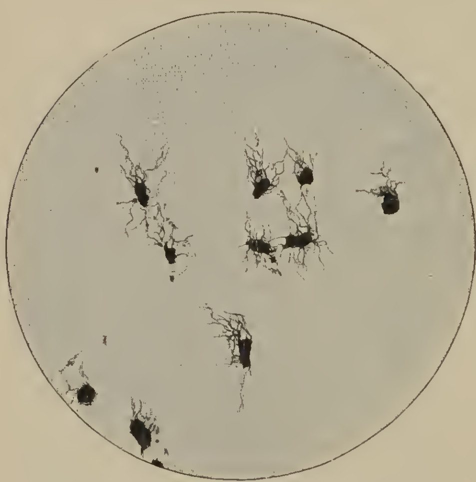


Fig. 230.—Typhoid bacilli with numerous fine flagella.

Reproduction of Bacteria.—The bacteria multiply by division or fission; the cells become somewhat increased in length, and form two separate and distinct individuals, or they remain adherent to each other after division (diplococcus, streptococcus, vibrio). The multiplying power of the fission fungi is enormous. If, as Flügge says, the average length of time required for fission to occur is one hour, there will be formed from each bacterium within twenty-four hours about sixteen million new ones. Bacteria, such as the bacillus subtilis, the bacillus anthracis, and the bacillus megaterium, propagate themselves by the formation of spores, which is an actual fructification in the interior of the cells—that is, by the formation of a

strongly refracting, shining body, which is set free by the atrophy of the remainder of the cells (Fig. 231). Each cell only forms a single spore. If the spores find lodgement in a nutritive medium, they sooner

Fig. 231.—Formation of spores in anthrax bacilli (Koch): *a*, From the spleen of a mouse after twenty-four hours' culture, × 650; *b*, germination of the spores, × 650; *c*, specimen *b* magnified 1,650 times.

or later germinate, and each spore will develop into a cell similar to the mother cell from which the spore originated. Spore formation has been observed in various species of bacilli and in some of the spirilla, but hitherto in none of the micrococci. The bacteria undergo spore formation for the purpose of propagating the species, particularly when at the height of their development and when the conditions governing their nutrition and growth are at the best. By subjecting the protoplasm of the bacteria to certain injurious influences their power of spore formation can be temporarily or permanently arrested (Lehmann, Behring, etc.). From a pathological standpoint the capability which the spores possess of withstanding noxious influences, such as dryness, heat, cold, or chemical substances, is of great importance. The spores of many bacteria can retain their vitality unimpaired for as much as a year when kept in a dry condition, or even in absolute alcohol. A dry heat of 140° C. (284° F.) destroys their power of reproduction with certainty only after many hours, and they can withstand boiling for several minutes. Globig had to subject the spores of the potato bacillus to the action of steam for more than four hours before they died. This great power of resistance which spores possess is perhaps due to the remarkably tough character of their enveloping membrane. The spores of the different kinds of bacteria vary very much in their capabilities of resisting noxious conditions.

Arthrospores.—Besides the endospores, or those which are formed in the interior of the cells, there are also arthrospores. They owe

their existence to the fact that certain segments of a chain, string, or cluster of bacteria have more vitality than the others and serve to propagate the species after the death of the remainder of the bacteria. The arthrospores have no other typical means of recognition, and they are not particularly resistant to unfavourable influences.

The occurrence of Bacteria and the conditions suitable for their Life.—Bacteria are found everywhere. The air, earth, water, and the things which they contain, our clothing, our food, skin, etc., support a vast number of these invisible living beings or plants, and only the normal organs, the blood and the lymph in the healthy body of man and animals, are free from them. Bacteria do not originate by spontaneous generation, or generatio æquivoca—i. e., by springing from molecules of another kind—but they grow only from spores of their own species (Pasteur and others). The above-described spores are the principal means for the preservation of the various kinds of bacteria.

From the fact that bacteria are found almost everywhere, it follows that they require but little for their development; the smallest amount of organic material is capable of supporting them. They require chiefly nitrogen and compounds of carbon. The amount of nutritive matter which the different species need varies very much, but in general they require, besides inorganic material, food which contains nitrogen (albumen), or is free from nitrogen (sugar, glycerine). It is very important that the nutritive medium should be alkaline, or at least neutral in reaction, as bacteria, with a few exceptions, do not grow in an acid medium. The bacteria which grow exclusively in dead organic material are called the *obligate saprophytic*, while *the obligate parasitic bacteria* are those which only grow in the living body of a warm-blooded animal. But there are a vast number of bacteria which are saprophytic (living upon dead organic matter), and exist as parasites, the so-called *facultative parasitic* or *facultative saprophytic fungi*.

Adaptation of Bacteria to unsuitable Nutritive Media.—The bacteria have the power of adapting themselves gradually to media which are unfavourable to their development, and are thus able to accommodate themselves even to antiseptic solutions, like bichloride, when they are allowed to become gradually accustomed to it. Trambusti succeeded, in the case of Friedländer's pneumococcus and other bacteria (the anthrax bacillus and the staphylococcus pyogenes aureus, etc.), in increasing the concentration of the bichloride of mercury contained in the nutritive bouillon from 1 to 40,000 up to 1 to 2,000 without interfering with their development. But if, on the other hand, these microbes were placed immediately in a bichloride-bouillon mixture of a strength

of 1 part bichloride to 15,000 of bouillon, their development ceased immediately.

Influence of Oxygen.—Oxygen plays a very important part in the life of bacteria. Many species will only grow in the presence of free oxygen (*obligate aërobic bacteria*), while the *obligate anaëarobic bacteria* will only do so when free oxygen is absent from their nutritive medium. Other bacteria—and they include the majority of the pathogenic bacteria—are facultative aërobic and facultative anaërobic ; i. e., their growth is not dependent on the presence of oxygen, though the facultative aërobic flourish better *with* oxygen, and the anaërobic *without* it.

Influence of Temperature.—Temperature has an important influence upon them. A certain amount of warmth is, of course, necessary for the development of bacteria as well as for any kind of life, and each species has its own temperature—that is, there is a range of temperature for each species which is best adapted for the growth of that species. The saprophytes are best suited by the ordinary temperature of a room (20° to 25° C.—68° to 77° F.), the parasites by blood heat (35° to 40° C.—95° to 104° F.), while other classes are capable of growing at temperatures close above the freezing point, and even below it. When the temperature is abnormally high or low the bacteria become benumbed by the heat or cold, and if the temperature rises or falls still more they perish. It is well known that the spores have a remarkable power of resisting extremes of temperature. The limits of temperature compatible with the development of most of them lie between 40° and 50° C. (104° to 122° F.); of others, between 60° and 70° C. (150° to 168° F.). The pus cocci, when in a dry state, can retain their vitality for a long time at a temperature of 80° C. (186° F.). Globig and Miquel have discovered bacteria which can still grow and multiply at a temperature ranging between 60° and 70° C. (150° to 168° F.).

Influence of Light.—Exposure to sunlight has a deleterious effect upon certain bacteria, such as the tubercle and anthrax bacilli, which die comparatively quickly under the direct action of the sun.

Influence of the Constant Electric Current.—The constant electric current appears to have only a slight or no injurious influence at all upon the development of bacteria.

The Products of the Life and Metabolism of the Bacteria.—By means of their vital activity the bacteria generate certain products of metabolism, of which some exert a restraining influence upon the growth of the bacteria ; such products are carbonic acid, lactic acid, acetic acid, etc. ; upon other species of bacteria the increasing alkalinity of the nutritive medium acts unfavourably. Many bacteria generate ferments or soluble organic bodies which readily change such complicated insoluble

compounds as albumen or starch into soluble substances, acting in the same way as the pepsin or ptyalin does in animals. In many bacteria there is a peptonising ferment which will liquefy gelatine, and this is a matter of much importance for diagnostic purposes. In fact, the various species of bacteria have been divided into the general classes of those which liquefy and do not liquefy gelatine.

Toxines or Ptomaines.—The bacteria are the cause of all fermentation and decomposition. Pathologically, there is a very important series of poisons called toxines, which are a part of the metabolic products of the bacteria. Some of these toxines belong to the organic bases resulting from decomposition (cadaver alkaloids or ptomaines) and some to the albumens and albumenoids (toxalbumens). The toxalbumens are formed by the action of the pathogenic bacteria upon the albumen of the affected tissues. The ptomaines—or, better, the toxines—produced in decomposing matter have long been known to possess toxic properties. In 1863, Panum isolated cadaverine from this source, and Bergmann and Schmiedberg found a crystalline body which they called sepsine. Selmi was the first to name these bodies properly, calling them ptomaines or cadaver alkaloids. Nencki was the first to obtain one of them in a pure state—collidin—and thus to ascertain its composition. Brieger and others experimented with ptomaines, or rather toxines, and obtained from cultures of bacteria many toxines in a pure state, such as peptotoxine, neurine, neuridine, choline, etc., and extremely poisonous toxines from cultures of cholera, typhoid, and tetanus bacilli. Their highly toxic character was demonstrated by inoculations upon animals. Many ptomaines or toxines have an effect similar to morphine, curare, or atropine. Peptotoxine causes death in the animals experimented upon with symptoms of paralysis; and neurin, according to Brieger, acts like muscarine, causing salivation, contraction of the pupils, disturbances of respiration and circulation, and chronic spasms. This explains the general systemic poisoning of various kinds due to bacterial infection of wounds, and in part the cases of poisoning caused by ingestion of decomposing food with the ptomaines it contains (meat, sausage, milk, and cheese poisoning). The toxines can be separated from the bacteria by filtration through porcelain, and then, by injecting the toxines beneath the skin of animals, it is possible to study their poisonous manifestations, such as severe gastro-enteritis, nervous disturbances, cramps, etc. If cultures of bacteria are subjected to a temperature of 60° C., the micro-organisms will perish, and the poisonous effects of many of the ptomaines can be studied, but the toxalbumens will have been destroyed. The nature and composition of the nutritive medium plays an important part in the formation of the toxines

produced by any particular kind of bacteria—i. e., the same bacteria do not under all circumstances produce the same toxines. Even harmless bacteria, like the micrococcus prodigiosus, may, when combined with some second species also non-pathogenic, become dangerous to the animal economy. The specific poisons of many bacteria—for example, the tubercle bacilli—are not found in the nutritive medium, but chiefly in the bodies of the bacteria themselves, so that tuberculosis can be excited by dead tubercle bacilli (R. Koch, Prudden, Hodenpyl, etc.). It was long ago demonstrated by Buchner that poisonous proteins which are capable of exciting inflammation are very apt to be present in the bodies of the bacteria. Buchner, Lange, and F. Roemer pointed out that these poisonous bacterial proteins have a great power of attraction for the leucocytes (chemotaxis), and after intravenous injection cause an increase in the number of the leucocytes (leucocytosis).

Pigment Formation.—Many bacteria form colouring matter (Fig. 232) of many different shades, such as white, black, red, blue, green, and brown, giving to the culture, and often to a great part of the nutritive medium, a characteristic tinge. The pigment bacteria, in all probability, possess a chromogenic body, which when exposed to the influence of oxygen changes to a colouring matter.

Fig. 232.—Staphylococcus pyogenes citreus, potato culture.

Phosphorescence.—Many bacteria are phosphorescent—i. e., they are luminous in the dark (Fischer).

Products of the Bacteria — Different Effects of the Products.—Arloing and Courmont distinguish three principal classes of the products of the pathogenic bacteria : 1. The substances precipitable by alcohol (diastases), by acidified alcohol (toxalbumens), by Millon's reagent (peptones). Diastases and toxalbumens are capable of dialysis only to a slight extent. 2. The substances which are soluble in alcohol and ether and can be precipitated by acetate of lead and bichloride of mercury are dialysable and are but slightly altered by heat (ptomaines, alkaloids). 3. The volatile substances, coloured compounds of carbon, etc. Some of the products have toxic, some predisposing, and some immunifying properties, and they have all been isolated from various species of bacteria (Behring, Fränkel, Rovet, etc.).

The marasmus accompanying acute and chronic diseases due to bacterial infection is caused by the products of the metabolism of the bacteria, as Mannetti has proved in the case of the metabolic products of the staphylococcus pyogenes aureus and albus.

The Limitations to the Growth of Bacteria; their Death.—Various influences place restraints upon the growth of the bacteria, such as too low or too high temperatures, absence of water, the addition of certain chemical substances or bacterial poisons to their nutritive medium, etc.

If noxious influences are not permitted to act too intensely upon the bacteria the latter become weakened, and this weakening process can be kept up through several generations, causing the pathogenic species to lose their virulence partially or completely. Cultures of bacteria which have been thus weakened have often been employed for inoculating purposes as a prophylactic measure against infectious diseases.

If the above-mentioned noxious influences are permitted to act too intensely or too long the bacteria will finally die. It is possible to kill bacteria by a great number of chemical substances, the chief of which are our commonly used antiseptics, bichloride of mercury and carbolic acid, provided they are employed in sufficiently concentrated solutions. Bacteria may also be destroyed by insufficient nourishment, by deprivation of water, by exposure to the direct rays of the sun, or by other antagonistic bacteria or the products of their metabolism (acids, alkalies), and especially by abnormally low or high temperatures, ranging from 50° to 80° C. (122° to 176° F.) and higher. As we have said before, low temperatures are less injurious, as a general thing, than abnormally high temperatures. Many of those bacteria which do not form spores, and the majority of the kinds which do, are capable of retaining their vitality in ice. The spores are also very resistant to high grades of temperature, ranging between 50° and 80° C. In general, they are killed only at a temperature of 100° C., some of them needing to be subjected to it from two to ten minutes, and others several hours. Budding, sprouting spores are more rapidly killed than those which have not budded. The most effective manner of destroying bacteria is by subjecting them to boiling water or hot steam. Dry heat, at a temperature of 140° to 160° C. (284° to 320° F.), requires three hours to kill bacteria, while boiling water or steam only requires from five to ten minutes. According to Tassinari, tobacco smoke has a decided bactericidal power.

Tests and Comparisons of the Germicidal Substances.—The efficacy of a germicide is tested by inoculating the bacterial matter previously subjected to its influence upon living animals and observing whether or not infection follows, or fresh moist or dried colonies may be placed upon glass slides, silk threads, grains of sand, etc., and thus brought into contact for a certain length of time with the germicide that is to be tested. The colonies thus treated are then placed in some nutritive medium, such as gelatine or bou-

illon, and kept at a temperature of 35° C. (77° F.). If chemical substances are to be tested, the glass slides or threads, etc., must first be washed in sterilised distilled water to prevent them from carrying any of the poison into the nutritive gelatine, and consequently restraining the growth of the bacteria. After the cultures have been kept at the proper temperature for several days, and have shown no development of colonies of bacteria, it may be inferred that the previously existing organisms have been killed by the substance in question.

Ordinary Methods of studying Bacteria.—The bacteriological methods of investigation consist principally in the study of stained preparations under the microscope, and in experiments with cultivation, and in reinoculation of the artificially cultivated bacteria upon living animals. The microscopical part of the investigation of bacteria has been greatly advanced by Robert Koch, who showed the necessity of homogeneous immersion and the proper way of using Abbé's condenser or illuminating apparatus. The basic aniline dyes are the best materials for staining both the bacteria and the cell nuclei. We employ aqueous solutions of gentian violet, fuchsin, and especially methylene blue, made in the last instance by thirty centimetres of a concentrated alcoholic solution of methylene blue, one hundred centimetres of water, and twenty drops of a one-per-cent. caustic-potash solution. If it is desired to make a preparation rapidly from a fluid containing bacteria, a drop of the liquid is evaporated upon a cover-glass. The residue is fixed by passing the cover-glass three times through the flame of a Bunsen burner, and then placing it for a few minutes in one of the above-mentioned staining solutions—methylene blue, for example. The excess of colouring matter is then washed from the cover-glass with distilled water, the specimen placed upon a slide and examined in the bright light provided by the Abbé condenser, with or without a blender. The importance of the Abbé condenser lies in the fact that it brings into prominence the coloured portions of the stained preparation, especially the nuclei and the bacteria. When unstained objects are to be examined the use of the condenser is to be restricted—i. e., a narrow blender is to be used, and less light allowed to fall upon the slide. In examining with the microscope fluids containing bacteria, it is a good plan to use hollowed-out slides. For the recent methods of staining bacteria I must refer the reader to the text-books of Fränkel, Hueppe, Gunther, Eisenberg, and others.

Culture Methods—The Various Kinds of Culture Media.—By artificial cultures of bacteria, and their subsequent inoculation upon animals, our knowledge of the effects produced by bacteria has been very much advanced. Bacteria are cultivated partly in liquid and partly in solid nutritive media. The vessels for conducting the experiments are exposed to dry heat at a temperature of 160° C., in a sterilising apparatus, for from one to two hours, while the nutritive media are sterilised in advance in a Papin's digester, or by steam, in order to kill the bacteria which may already be existing in them.

The fluid nutritive media (infusion of meat, infusion of hay, milk, urine, blood serum, etc.) are inferior in every respect to the translucent solid media (gelatine, agar-agar). In the liquid media it is possible to watch the growth, increase, and finally the spore formation, by means of "cultures in hanging drops." With the aid of a sterilised platinum wire hook a drop of the sterilised

nutritive liquid is placed upon a cover-glass which has just been heated; to the drop is then added a very small amount of the culture. A concave glass slide is sterilised by heat, vaseline placed around the concavity, and the cover-glass laid upon the vaseline circle, with the drop of nutritive liquid dipping into the concavity. The solid nutritive media (gelatine, agar-agar) become fluid at temperatures between 25° and 30° C. and 35° and 40° C., respectively, but solidify rapidly on cooling. If bacteria are planted in the most commonly used nutritive gelatine (bouillon, eight per cent. gelatine, one per cent. peptone, one-half per cent. common salt), which has been heated to a temperature of 30° C. in a test tube, and so liquefied, and if the well-mixed fluid is then poured upon sterilised glass plates or saucers, the bacteria will grow in the rapidly hardening gelatine, and after the lapse of one or two days will form visible cultures. The microscope shows that each colony is made up of individuals of the same species. To prevent the colonies from growing too thickly, it is best to dilute the gelatine first infected, and to pour the diluted liquid upon a larger number of glass plates, a portion of the nutritive medium in the first glass being emptied into a second, to which gelatine is then added, and this last fluid is then mixed with more gelatine in still a third glass. All the mixtures are then poured into a little shallow glass dish. The agar mixture, which remains solid up to a temperature of 38° C., is employed for bacteria requiring a temperature higher than 25° C. It is thus possible to make cultures of any desired species of bacteria in a solid medium. The cut surfaces of slices of a boiled potato are also much used as a solid nutritive medium, and distinct colonies can be made to grow upon them by spreading out over the surface of the potato thus prepared a single drop of liquid containing three or four species of bacteria. Under proper conditions every bacterium will then develop into a separate colony.

The different species of bacteria require particular kinds of nutritive media—blood serum, for instance—while other species must have media which do not contain oxygen. The latter requirement is obtained by a thick layer of gelatine or agar, or by supplanting the air in the culture vessel by hydrogen gas, or by the addition of reducing substances (one to two per cent. dextrose, formate of sodium, pyrocatechin, etc.). A number of known bacteria have as yet eluded all attempts at cultivation. The behaviour of the cultures in the nutritive media, such as gelatine or agar, can now be watched very exactly. Some species, for example, form dry white masses, others white slimy drops, and still other colonies liquefy the gelatine, or develop into colonies having a bright red, yellow, or green colour, etc.

If a cover-glass placed upon the gelatine plate is pressed lightly on the colonies growing upon the surface, and then lifted off, a portion of the colony will cling to the glass. This cover-glass preparation is then passed three times slowly through the Bunsen flame, treated with a drop of fuchsin or gentian violet, washed with water, and examined under the microscope.

Needle-point Cultivation.—The needle-point cultures are especially important (Fig. 233), and are made in the following manner: A platinum wire is brought into contact with some particular colony of bacteria, and then plunged into nutritive gelatine contained in a glass test-tube. In the region of the puncture the characteristic culture will develop.

Linear Cultures.—When a linear culture is made the gelatine is allowed

to harden, so that its surface forms a plane obliquely directed towards the sides of the test tube, and over this surface is lightly drawn the platinum wire which carries the bacteria.

Of course care must be taken in both the needle-point and linear cultivations that only the particular species of bacteria to be investigated is introduced.

These few general remarks on the methods of investigation pursued in bacteriology will suffice for our purpose. More detailed descriptions can be had by reference to the text-books of C. Fränkel, Flügge, Hueppe, and others.

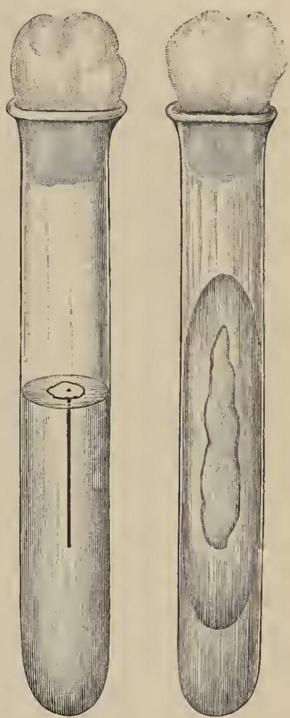


Fig. 233.—*A*, stab or puncture culture; *B*, linear culture.

The Action of Pathogenic Bacteria—Methods of Transmission, and Experimental Inoculation of Animals.—The boundaries between the noxious, disease-producing or pathogenic bacteria and the non-pathogenic are not very sharply defined. Even non-pathogenic bacteria can under certain conditions, as before remarked, do a great deal of harm, while, on the other hand, even virulently pathogenic micro-organisms may in various ways, such as by peculiar methods of cultivation, be rendered weak or entirely inert (see page 266).

How do the pathogenic bacteria act? The pathogenic bacteria produce their noxious effects, in the first place, by forming specific, extremely poisonous products of metabolism (toxines, ptomaines, toxalbumens, etc.) which damage the animal organism in a definite way. Other species of bacteria become dangerous to the animal economy on account of their great numbers. They increase with great rapidity and spread throughout the body, as is the case with the anthrax bacilli, which in a purely mechanical way produce very serious changes in the different organs, and prove fatal by consuming the nutritive matter, albuminous substances, and oxygen, which are necessary to the life of the organism.

Toxic and Infectious Bacteria.—The first class of bacteria are the toxic, the second are the infectious. The toxic bacteria form their poisons outside of the body only, and are incapable of developing inside the living body. If they gain access in sufficient numbers to poison the body they are carried to all the different organs by the circulating blood, and can be perhaps demonstrated in them here and there; but

their presence is of secondary importance, as the main thing is the poison which they have produced, upon the kind and amount of which the disease depends. Cultures of the toxic bacteria, whether living or not, will, when inoculated in animals, poison them. The infectious bacteria, on the other hand, possess the power of multiplying within the organism in which they find lodgment, and of spreading themselves through it; and even though very few in number when first introduced, they can increase with incredible rapidity, flooding, as it were, all the organs of the body. The anthrax bacillus is a good example of this variety (see § 77). Hand in hand with the increase in the number of the micro-organisms goes an increased formation of the poisonous products of their metabolism, leading to intoxication (poisoning) of the body. The original infection may be produced by the entrance into the body of an exceedingly small number of microbes. The same species of bacteria may prove infectious for one kind of animal but not for another; but by feeding an animal in a certain way, or by subjecting a particular species of bacteria to proper cultivation, the animal may be rendered susceptible or not to the particular species of bacteria. The glanders bacillus has an exceedingly virulent effect upon field-mice, but white mice are not affected by it. If, however, the white mice are fed upon phoridzin until they become diabetic, they change and are then susceptible to this bacillus. According to Arloing's statement, the bacilli of malignant œdema become infectious for such animals as are ordinarily not affected by them if the animals, previous to their inoculation, are soaked in a twenty-per-cent. solution of lactic acid, or if their tissues are first treated with pyrogallic or carbolic acids, or bichloride of mercury.

Attenuation of the Virulence of Bacteria.—It has hitherto been impossible to effect a lasting or permanent increase in the virulence of the bacteria, or to change the toxic bacteria into the infectious class, or *vice versâ*; but, on the other hand, a lasting attenuation and even a total destruction of their virulence is possible, as in the case of the bacilli of chicken cholera and anthrax, the pneumococci, etc. (Pasteur, Toussaint). This attenuation of the virulence of pathogenic bacteria may be brought about in a natural as well as in an artificial way. The natural attenuation will take place, as demonstrated by Flügge's experiments, in such infectious bacteria as are compelled to grow for a long time under conditions differing from those governing their ordinary existence and development, such conditions being represented by artificial nutritive media or atmospheric surroundings to which they are not accustomed. By causing certain bacteria to accommodate themselves to growth upon dead substances—that is, giving them a sapro-

phytic method of life—their capability of developing in the animal organism is lost. A similar loss of specific action can be produced in saprophytic bacteria by cultivating them under altered conditions (Hueppe and others). The virulence of bacteria can also be modified, and even permanently abolished, by subjecting them to various influences which are injurious to them. The poisonous character of anthrax bacilli has thus been rendered weaker or destroyed by cultivation of the organisms in antiseptic or disinfecting nutritive media, such as bouillon containing bichromate of potassium (1 to 2,000 – 5,000), or blood containing one per cent. of carbolic acid, or by cultivation under a pressure of eight atmospheres, or by exposure of the culture to the direct rays of the sun. Likewise, by breeding a special species of bacteria several times in animals which are not susceptible to it, the virulence of this species can be diminished. The surest and most usual way of "attenuating their virus" is the cultivation of bacteria in high temperatures; and the lower the temperature that one uses for bringing this about the longer the process of attenuation will take, but it becomes just so much the more permanent, so that the weakened poisonous character of the bacteria is transmitted to their offspring, and in this way it is possible to make a series of completely attenuated cultures. The attenuated differ, in all probability, from the virulent bacteria in possessing a degenerated protoplasm, a defective vitality, a diminished power of growth, less ability to withstand injurious influences, and especially in having different products of metabolism. Virulent anthrax bacilli, for example, form a greater amount of acid than the attenuated ones. Therefore, bacteria which have been attenuated or weakened do not flourish in the animal system, as they are incapable of overcoming its natural oppositions or hindrances to their growth, and they die relatively quickly either at the point of infection, or in the blood, and especially in the organs where they are deposited by the blood—viz., the liver, spleen, and marrow of the bones.

Power possessed by the Animal Organism of protecting itself against Bacteria.—The healthy animal or human body possesses various means of protecting itself against the entrance of bacteria. The serum of the blood, particularly if free from cellular elements, has a direct germicidal power, as has been demonstrated by the beautiful experiments of Buchner, Niessen, Stern, and others. This germicidal power is confined exclusively to the plasma, while the cellular elements, the red and white blood-cells, are antagonistic to it. The germicidal power of the blood in a given individual appears to have a different intensity at different times. According to H. Buchner, it is dependent upon the proportion of salts it contains. Fodor says that the germicidal power

of the blood is increased as its temperature is raised and as it becomes more alkaline by the addition of alkaline substances. At a temperature of 38° to 40° C. (100·4° to 104° F.) the germicidal action of the blood is greatest, but above 40° C. (104° F.) it rapidly decreases. At all events, it is mainly by chemical processes, if we leave out of consideration the local anatomical peculiarities, that the animal organism protects itself against the entrance of bacteria. Up to a certain point there is also a conflict between the bacterial cells and the cells in the body of the animal. According to Metschnikoff, it is principally the white blood-cells which take up and devour the bacteria (Fig. 234), and for this reason he has called them devouring cells—phagocytes—and to them he ascribes the most important part in the battle of the system with the bacteria which have entered it. This phagocyte theory of Metschnikoff's has recently been successfully attacked by Flügge, Baumgarten, and others. The consensus of opinion at present is that, contrary to Metschnikoff's idea, the white blood-corpuscles are the ones which succumb in the conflict with the bacteria, if the latter enter the corpuscles in a living condition, and only dead bacteria are carried away by the cells of the body. In addition, the bacteria are carried away chiefly in the excretions, especially in the fæces, urine, saliva, and sweat (Brunner, Eiselsberg).

Fig. 234.—Phagocytes (Metschnikoff). *a*, an anthrax bacillus about to enter a white blood corpuscle; *b*, the anthrax bacillus within the white blood corpuscle; *c*, white blood corpuscle with anthrax bacilli which have become broken into pieces.

Natural or acquired Immunity of Animals and Man towards Bacteria.—The existence of immunity in man or animals towards this or that species of bacteria is a matter of great practical importance. It is in part hereditary and in part artificially acquired. We know that, owing to Jenner's discovery of the last century, man can be made to lose his susceptibility to variola by means of the inoculation with cow-pox virus. The discoveries of Pasteur are in harmony with this important fact—namely, that by inoculation of a weakened bacterial poison the system is rendered non-susceptible to infection by the poison of such diseases as hydrophobia, anthrax, chicken cholera, etc. Though Koch, Löffler and others have demonstrated, as regards anthrax, that inoculation with the weakened or attenuated anthrax poison provides no certain and absolute protection against this disease, yet scientifically and practically, the fact remains established that the

animal system can under certain circumstances, by inoculation with the attenuated bacterial poison, be made unsusceptible to the most virulent substances—in other words, the system becomes artificially immune. The active principles of the substances used in inoculation or vaccination are chemical bodies, or the products of the metabolism of the bacteria themselves. Numerous hypotheses have been advanced for the explanation of this acquired immunity. Pasteur, Klebs and others hold that it depends upon the fact that during the first invasion a quantity of substances are consumed which are essential to the life of the bacteria in question (exhaustion theory). Chauveau believes, on the contrary, that during the first invasion of the bacteria metabolic products form from them, which remain behind and make it impossible for infection to occur from the same species (retention hypothesis). Metschnikoff employs his phagocyte theory for explaining acquired immunity. C. Fränkel is probably right in saying that the acquired toleration of a poison, or immunity, is not a single process, but is brought about now in this way and now in that. It is possible that the exhaustion or retention hypothesis, or Metschnikoff's cell theory, or the chemical action of the blood and tissue fluid, all play an important part, but we are not yet sufficiently familiar with all the facts which bear upon this question to answer it definitely.

Great interest attaches to the experiments of Wooldridge, Kitasato and Behring upon the artificial production of immunity towards anthrax, tetanus, and diphtheria. Wooldridge discovered that solutions of fibrinogen, after having served as media for the cultivation of anthrax, made an animal immune to infection from anthrax; but, on the other hand, he obtained this immunity by producing a slight chemical alteration in the fibrinogen, without making use of the anthrax bacilli. Behring and Kitasato made rabbits immune towards tetanus by means of trichloride of iodine. Behring rendered animals unsusceptible to diphtheria by (1) employing cultures which were sterilised or had been treated with trichloride of iodine; (2) by the subcutaneous and intra-abdominal injection of the pleuritic exudate which frequently develops in animals which have diphtheria, and also by the subcutaneous injection of the trichloride of iodine very soon after the diphtheritic infection. The capability of animals for resisting diphtheria was rendered greater by the use of hydrogen peroxide. The blood of such immune animals possesses the power of destroying the poison of the disease, and consequently their serum has been used for subcutaneous injection in cases of diphtheria and tetanus in man, but hitherto with doubtful results.

Acquired immunity has a very close relationship with the recovery

from infections diseases. The latter would not be so difficult if the germicidal substances which are known to us had the same effect in the body as in the test tube; but such is not the case. In all probability the antagonism existing between many species of bacteria plays an important part in recovery from an infectious disease. For instance, the bacillus fluorescens putridus is a pronounced antagonist to the cocci of suppuration and the bacillus of pneumonia and typhoid, and if this bacillus is implanted in gelatine, the latter becomes incapable of infection by the above-mentioned organisms. Emmerich was able to save rabbits inoculated with anthrax from sure death by placing in their blood-vessels, either before or after the anthrax infection, a large number of the erysipelas cocci or of the micrococci prodigiosi or of the bacilli pyocyanei. The animals, however, were not rendered immune to a second infection of anthrax.

Technique of Experimental Transmission of Bacteria from Animal to Animal.—Under the heading of pathogenic bacteria which have a specific importance, we class those which are capable of demonstration in all cases of any particular disease, and in no other disease, and are present in such numbers and have such a distribution in the tissues that they readily account for all the symptoms of this particular disease. The certainty of the specific character of a particular species of bacteria is established by its examination under the microscope, artificial cultivation, and inoculation. If an animal dies from a bacterial disease, the post-mortem examination is conducted with the most rigorous asepsis, to prevent the blood and organs of the animal from becoming contaminated with any other bacteria. The skin is washed in a one-tenth-per-cent. solution of bichloride of mercury, and the instruments are sterilised by passing them through the flame of a spirit lamp. After the skin of the animal has been sufficiently removed, the abdominal and thoracic cavities are opened with sterilised instruments which have not before been used, so that no bacteria shall be introduced. Then the organs are examined in the following order: spleen, liver, kidneys, heart, and lungs. Small portions of the blood and spleen, liver and lungs are placed in nutritive fluids, and after the latter have been poured upon culture plates in the usual diluted condition before described, it will be possible to determine whether bacteria are present, and of what species they are. Parasitic bacteria which will only grow at body temperatures are cultivated on agar plates kept in a culture oven. The colonies which develop upon the plates are then examined, and it is determined whether there are one or more species present, and which is the most numerous. Then follow the inoculation experiments of the pure cultures upon animals, such as mice, guinea-pigs, rabbits,

monkeys, pigeons, and dogs, for the purpose of exciting a disease similar in all respects to the primary one. The inoculation is done by simple subcutaneous puncture, by making an incision and inserting the culture beneath the skin, by placing it in the anterior chamber of the eye, by injecting it into the blood-vessels or into the peritoneal or abdominal cavities, by incorporating the culture in the food, or introducing it with the œsophageal bougie, or by permitting it to be inhaled, as Buchner did, by mixing the culture with sterilised water or bouillon, and then scattering this by means of a spray apparatus as a fine mist containing the bacteria.

Intra-uterine transmission of Micro-organisms from the Mother to the Fœtus.—The possibility of the transmission of micro-organisms from the mother to the fœtus is of great pathological interest. That pathogenic micro-organisms can pass from the mother to the fœtus has been proved partly by cases of anthrax infection which have occurred in man, and partly by experiments upon animals (chicken cholera, septicæmia in rabbits, malignant œdema). Birch-Hirschfeld has made a careful microscopic study of the placenta in pregnant goats, rabbits, white mice, and bitches suffering from anthrax, and he found the bacilli in both the placenta and in the fœtal tissues, but in very different amounts in the different animals experimented upon. He affirms that the healthy placenta will not ordinarily permit of the direct passage into the fœtal circulation of either finely divided foreign bodies incapable of increase in numbers, or of micro-organisms; but the placenta, without necessarily undergoing any gross mechanical changes (rupture of the chorionic villi or of the maternal vessels, hæmorrhages), may become pervious from the effects produced by the micro-organisms circulating through it. Micro-organisms, such as the anthrax bacilli, can, when present in vast numbers, penetrate into the fœtal portion of the placenta if assisted by alterations in the tissues forming the walls of the blood sinuses, and by lesions in the epithelium of the villi. These changes can be brought about by the injurious effects due to the growth of the bacteria. (See also § 83, Tuberculosis.)

Non-pathogenic Bacteria.—C. Fränkel gives the following as the principal non-pathogenic bacteria: 1, Micrococcus prodigiosus; 2, bacillus indicus; 3, yellow, white, orange, and red; 4, bacillus megaterium; 5, potato bacillus; 6, bacillus subtilis; 7, bacillus figurans; 8, bacillus acidi lactici; 9, bacillus butyricus, clostridium butyricus; 10, bacillus of blue milk; 11, bacteria of drinking-water (bacillus violaceus, bacillus fluorescens); 12, bacillus phosphorescens; 13, bacterium phosphorescens; 14, bacterium termo; 15, proteus vulgaris; 16, bacillus spinosus; 17, spirillum rubrum; 18, spirillum centricum. For further description of these, reference should be made to the textbooks of Flügge, C. Fränkel, and others.

Pathogenic Bacteria.—The pathogenic bacteria are the following:

1, Bacillus anthracis; 2, bacillus of malignant œdema; 3, bacillus of pseudo-œdema; 4, bacillus of tuberculosis; 5, bacillus of leprosy; 6, bacillus of syphilis; 7, bacillus of glanders (bacill. mallei); 8, comma bacillus of Asiatic cholera; 9, Finkler-Prior's vibrio; 10, Deneke's vibrio; 11, vibrio Mitschnikoff; 12, Emmerich's bacillus; 13, bacillus of typhoid; 14, spirillum of relapsing fever (typhus recurrens); 15, plasmodium malariæ; 16, Friedländer's pneumococcus; 17, Fränkel's pneumonia bacillus; 18, bacillus of diphtheria; 19, bacillus of rhinoscleroma; 20, streptococcus of erysipelas; 21, staphylococcus pyogenes aureus; 22, and citreus; 23, and albus; 24, streptococcus pyogenes; 25, bacillus pyocyaneus; 26, gonococcus; 27, bacillus of tetanus; 28, bacillus of chicken cholera; 29, bacterium of hæmorrhagic septicæmia (rabbit septicæmia, swine fever); 30, bacillus of swine erysipelas; 31, bacillus of mouse septicæmia; 32, micrococcus tetragenus. I shall refer again to the bacteria which are of the most importance from a surgical standpoint under the chapters dealing with the infectious diseases.

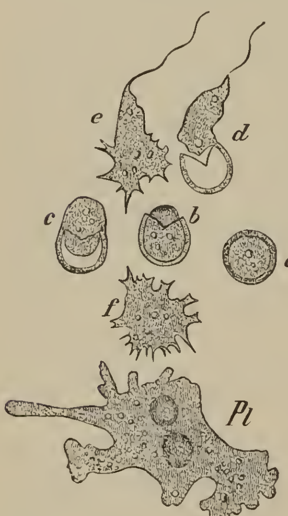


FIG. 235.—*Pl*, young plasmodium from chondriodcrma difforme, containing two spores; *a*, ungerminated spores (trichia vera); *b–d*, exit of the zoöspores from the torn spore membrane; *e*, ciliated, *f*, nonciliated amœboid zoöspores (De Barry).

The Mycetozoa and Protozoa.—We must briefly discuss the mycetozoa and protozoa which play an important part in the most recent pathological investigations upon man and animals. The mycetozoa or myxomycetes are neither animals nor plants, but a group of living organisms midway between the two, though nearer to the amœbæ, the lowest form of animal life, than to the bacteria, or most elementary plants. The young mycetozoa form slimy masses of protoplasm (plasmodia), changing later into vesicles with an enveloping membrane containing spores, and particularly zoöspores, which move about partly by means of a waving flagellum (Fig. 235, *d*, *e*) and partly by the pulling out and drawing in of protoplasmic processes (Fig. 235, *f*). The zoöspores multiply for many generations by division of the cell into two parts, and finally two or more of these cells join and fuse together, forming again a protoplasmic body, or plasmodium, as it is called. The mycetozoa, the chief representatives of which are myxomycetes and the small group of acrasia, grow upon the decaying parts of plants, algæ, etc.; they are typical saprophytes, though some lead a parasitic life in plants. The plasmodiophora Brassicæ produces a destructive tumour-like disease in the roots of cabbage. The mycetozoa and micro-organisms related to them are also pathogenic for man and animals. Koch surmised this long ago, but it has only recently been proved.

The Protozoa.—The mycetozoa come next to the protozoa, which are usually looked upon as the lowest forms of animal life, but are not sharply defined from the lowest forms of plants. The protozoa consists partly of a single cell, partly of several similar cells, with a distinct differentiation of their protoplasms. They pass through several stages of development, as exemplified by the amœbæ, which are similar to the white blood-corpuscles, and which multiply by division, beginning with the nucleus.

Leuckart divides the protozoa into rhizopods, sporozoa, and infusoria. The rhizopods consist of unenclosed protoplasmic masses containing vacuoles and a nucleus. They multiply by division, live in solid nutritive media, and move by putting forth finger-like processes (pseudopodia). The sporozoa move about like worms by expansion and contraction; they multiply by means of spores, and live as parasites; they are nourished by fluids which pass by endosmosis through the cuticular envelope of the cell. This species of pathogenic protozoa is of considerable interest to both man and animals. The gregarines, living as parasites in insects and worms, belong to the sporozoön class, as do also the oval psorosperms, which lead a parasitic existence in mammals, and the cylindrical psorosperms, found in fishes and amphibia. The infusoria belong to the last division of protozoa; they do not change their shape; they possess cilia and an opening which answers for a mouth, and their protoplasm is made up of a cortical and medullary portion.

It has been proved by recent experiments that both the mycetozoa and protozoa are pathogenic as regards man. Golgi, in Paris (1886), showed that peculiar amœboid bodies were regularly present in the blood during intermittent fever and malaria, and were almost always to be found inside the red blood-corpuscles, in which they underwent lively amœboid movements.

Numerous observers have established the fact that this organism can be demonstrated in the blood in every case of malaria (the plasmodium malariæ). It has hitherto been impossible to cultivate the plasmodium malariæ artificially, but Celli and Marchiafava have produced malaria in healthy individuals by the intravenous injection of blood taken from malarial patients and containing the plasmodium. This fact does not necessarily prove the pathogenic significance of the plasmodium malariæ, but it has been established beyond a doubt by other experiments that this organism is the real cause of the malarial fever. It has also been proved that some severe forms of dysentery are due to a peculiar amœba (Kartalis, in Virch. Archiv, Bd. 105, p. 521), and molluscum contagiosum to a species of plasmodium. There have also been found mycetozoa and protozoa within the cells in various skin diseases, cutaneous ulcers, and cancers, but some authors doubt the truth of this.

§ 60. **General Remarks concerning Injuries.**—The injuries of the human body are divided into two main groups: injuries with and injuries without interruption of the continuity of the external coverings of the body, including both skin and mucous membrane. The former class we designate as open bleeding injuries, or, in short, as wounds; the latter as bloodless or subcutaneous injuries. This distinction is of the greatest practical importance, since the prognosis of any injury, apart

from the influence of the particular portion of the body involved, is chiefly dependent upon whether the overlying skin or mucous membrane has been divided or not. Every open wound, be it ever so small —for example the prick of a needle—may be the cause of an infectious wound disease, and under these circumstances may prove fatal to the patient. It must always be borne in mind, as we have learned in § 59, that the micro-organisms which are everywhere present outside the body may, by their admission to any wound, give rise to the gravest dangers. This cannot occur in subcutaneous injuries where the protecting skin and mucous membrane remain intact and ordinarily prevent the entrance of these noxious bodies into the system. The aim of the modern method of treating wounds is directed, as it should be, towards keeping out of the wound all injurious substances, including bacteria, and towards rendering them innocuous in case they have gained entrance. For this purpose we employ, in treating wounds, fluids which, like three-per-cent. solutions of carbolic acid and 1 to 1,000 to 1 to 5,000 solutions of bichloride of mercury, are capable of killing the micro-organisms; and, furthermore, we only bring in contact with the wound such objects as have been made perfectly sterile. A probe or a finger which has not been disinfected may cost the patient's life. In the chapter on fractures we shall see that in the pre-antiseptic periods of surgery the course of subcutaneous fractures was entirely different from that of fractures complicated by wounds of the skin. It was in the treatment of this latter class of injuries that Joseph Lister, the great reformer of modern surgery, began the practical application of his antiseptic, or we might say his antibacterial, method of treating wounds. Now we are enabled to keep a fresh wound free from all injurious substances—in other words, to prevent all infectious wound diseases—and to bring about a cure of a great number of injuries which in the pre-antiseptic days would undoubtedly have proved fatal.

According to the *causation* of the injury, we distinguish between injuries due to mechanical violence and those due to thermal (burning, freezing) or chemical influences (cauterisation). Subcutaneous injuries are produced by blows with blunt instruments, or falls, while open wounds are caused by blows with more or less sharp instruments, and take the form of punctured, lacerated, incised, contused, or gunshot wounds, etc. All wounds due to blows with blunt instruments are more or less contused wounds—that is, the borders of the wounds suffer a more or less extensive necrosis as a result of the violence used.

The pure incised, stab, and punctured wounds are simple wounds, while the lacerated and contused wounds are, as we shall see, complicated wounds. The condition of the borders and the depth of the wound

are matters of great practical importance. If a wound penetrates into a joint or into one of the large cavities of the body, such as the cranial, thoracic, or peritoneal cavities, we call it a penetrating wound. If a portion of tissue is completely cut or torn from its connections by violence, a wound is formed with loss of substance; but if the portion of tissue still retains some of its connections with the surrounding parts, there results what is called a flap or peel wound. A wound which is clean, not poisoned and not infected, is distinguished from one which is unclean, poisoned, and infected. We count amongst unclean wounds all those in which there is present any foreign body whatsoever, such as dust, sand, dirt of every description, portions of clothing, bullets, powder grains, etc. Wounds affected with any one of the infectious wound diseases belong to the class of infected wounds (inflammation, suppuration, erysipelas, wound diphtheria, septicæmia, etc.). The wounds produced by bites of snakes, insects, etc., are wounds poisoned by animal poisons.

The symptomatology and treatment of injuries vary greatly, according to the portion of the body involved and the anatomical peculiarities of the injured tissues. Consequently we divide injuries of the human body into injuries of soft parts, of bones, and of joints, and their symptomatology and treatment will be discussed later on. We shall first give a general outline of the anatomical changes occurring in the healing of a wound.

Railway Injuries.—A very severe and numerous class of injuries are incurred from collisions between railway trains. Tardieu, Vibert and others have recorded their valuable experiences on this subject, particularly Vibert, who gave a report of four hundred persons injured in a railroad accident at Charenton. The occupants of the train which moves the most rapidly suffer the worst and most numerous injuries. Upon those who die instantly without exhibiting any external injury many punctiform hæmorrhages are found, mostly about the head and upper portions of the body, similar to those which occur in fracture of the base of the skull. Bad fractures and injuries to the soft parts are found chiefly in the lower extremities, unless the victims protect themselves in time by rising from their seats. Not infrequently the lungs are injured (hæmoptysis) by contusion or crushing of the thorax, and there may also be injuries of the abdominal viscera. Very often the patients suffer grave disturbances of the central nervous system—loss of sleep, headache, alterations in their mental condition of a partly excitable, partly melancholic, depressed type, disturbances of digestion, loss of memory, easily excited intellectual fatigue, great susceptibility towards stimulants (alcohol, tobacco), maniacal conditions, auditory sensations of a subjective character, photophobia, paralysis of accommodation, disturbances of smell and taste, paræsthesia of the sensory nerves, anæsthetic areas, particularly when there is an organic lesion of the brain, muscular twitchings, motor weakness, especially in the legs, paralysis, disturbances of circulation and res-

piration (increasing cachexia). The patient exhibits, in some cases, every symptom of dementia paralytica. All these nervous phenomena are grouped together under the name of traumatic neuroses. They are particularly liable to make their appearance after concussion of the brain and spinal cord, and sometimes are caused by relatively slight accidents. In the majority of cases it is a psychosis and neurosis, similar to hysteria, without actual changes in the central nervous system (Charcot, Strümpell). Albin Hoffmann has correctly pointed out that a traumatic neurosis is of much less frequent occurrence in individuals previously perfectly healthy than has hitherto been supposed ; the number of malingerers is large, and is steadily increasing since the accident law went into effect. In the minority of the cases there do occur progressive pathological changes in the central nervous system as a direct result of the accident. The prognosis of these cases is very unfavourable ; they often lead to chronic disease of the cortex of the brain ; less frequently it is located in the spinal cord. The English physicians have given the name of railway spine to the secondary diseases of the central nervous system following railway accidents.

§ 61. **The Anatomical Phenomena in the Healing of a Wound.**—The *anatomical phenomena* manifested in the healing of wounds were first studied exhaustively by Thiersch, and all the recent investigations have been based upon the correct statements which he made. We ordinarily distinguish two kinds of repair in a wound : (1) the direct primary agglutination of the divided parts, called healing *per primam intentionem ;* and (2) the repair of a wound by the formation of granulation tissue, or, in other words, repair accompanied by suppuration, called healing *per secundam intentionem.*

Healing per Primam Intentionem.—Healing by primary intention takes place in all fresh aseptic wounds, particularly in those produced in the course of an operation, the borders of the latter class (operation wounds) being held by the stitches in continual contact until they adhere together. Those wounds which are treated aseptically heal more rapidly than those treated antiseptically—that is, than the wounds irritated by antiseptic solutions (bichloride, carbolic acid, etc.).

Macroscopic Phenomena in Healing by Primary Intention.—The macroscopic phenomena manifested in the healing of wounds *per primam intentionem* are briefly as follows : We ordinarily find, in the first place, that the borders of the wound become agglutinated by a coagulum made up of blood and lymph. During the next four, six, or eight days the union of the wound is definitely established, the coagulum in and around the wound space becoming replaced by new cells and blood-vessels, the former of which gradually change into the fibrillar connective tissue making up the cicatrix. In the case of small wounds, or slight losses of substance, there is usually developed as a result of the coagulation of the blood and lymph a crust, beneath

which the complete healing of the wound is accomplished (called healing under a scab (see page 177). The skinning over of the wound proceeds from its borders by proliferation of the cells of the rete Malpighii and of the sebaceous glands, if the latter still exist in the surface of the wound. The young cicatrix at first forms a fine red line, which subsequently becomes gradually whiter and softer. The cicatrices of many wounds which unite by primary intention disappear in course of time more or less completely.

Healing by Secondary Intention.—The healing *per secundam intentionem*, with the formation of granulation tissue and pus, takes place in badly contused wounds, or where there has been a loss of substance and it has been impossible to obtain direct adhesion of the divided tissues with the aid of stitches, and also in wounds which have been neglected and not treated aseptically, and in wounds which have been infected by micro-organisms.

Macroscopic Phenomena in the Healing of Wounds by Secondary Intention.—Macroscopically, the phenomena which take place in this form of healing of a wound, involving, for example, vascular soft parts, are somewhat as follows: Until the expiration of about twenty-four hours after the reception of the injury the various tissues exposed in the surface of the wound are clearly distinguishable from one another. Later on the outlines of the various tissues in the wound are obscured by a jelly-like covering consisting of a reddish-yellow fluid, a mixture of blood serum and lymph which has been poured out from the wound. After about two to three days the greyish-red gelatinous wound surface begins to take on a granular, red appearance, and the wound begins to granulate, or to form vascular cellular germinal tissue called granulation tissue, from which there is ordinarily produced an exudate containing a great quantity of round cells—in other words, pus. If the wound heals aseptically as a result of most careful disinfection and most rigorous aseptic treatment, the secretion will be slight, and frequently actual pus formation will not take place. Profuse suppuration will only occur in a wound which is not aseptic.

In contused wounds with destruction, or rather necrosis, of the tissues, the dead portion of the tissues is first cast off by the process of granulation; the wound "purifies itself." Under these conditions it is possible to obtain with aseptic dressings a more rapid healing, unaccompanied by profuse secretion, suppuration, or decomposition.

The Skinning Over of a Granulating Wound.—The covering over of a granulating surface with skin proceeds gradually from the margins of the wound, and is accompanied by a simultaneous shrinkage of the granulation tissue. If the cutis has not been entirely destroyed, if

there are still traces of the Malpighian stratum present, or if the epithelium of the sebaceous glands is intact, the remains of these structures will form the starting points within the granulating area from which skin will spread outwards over the granulating surface. All cicatrices which are accompanied during their formation by suppuration are thicker, more extensive and unsightly than the small linear cicatrices resulting from primary union.

Histological Phenomena in the Healing of Wounds.—The *minute phenomena* which take place in the repair of a wound involving vascular

Fig. 236.—Wound in the liver (cuneiform excision), twenty-four hours old. *a*, Border of the liver; *b*, coagulum of blood in the defect. Commencing collection of wandering cells in the borders of the wound.

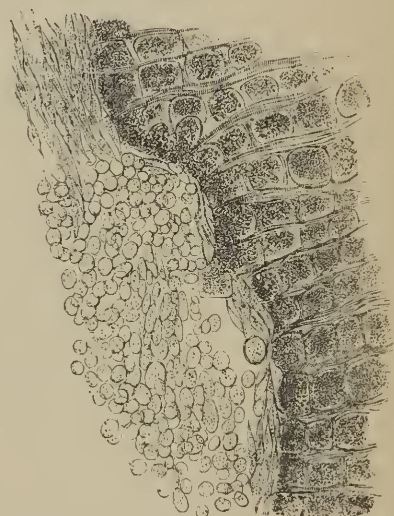


Fig. 237.—Immigrated white blood-corpuscles in a four-cornered defect in the middle of a dead, hardened piece of liver substance, which had been implanted with antiseptic precautions in the abdominal cavity of a rabbit twenty-four hours.

tissue is practically the same whether the wound heals with the formation of pus or without it. Healing by primary intention is characterised by the formation of a minimum amount of germinal tissue uniting the borders of the wound, while in healing by secondary intention the amount of germinal tissue is much more considerable. After every wound, no matter how free the healing may be from reaction, there follows an inflammation in the sense described in § 56, and as a result of this there is a cellular infiltration of the borders of the wound with wandering cells (Fig. 236). This cellular infiltration of the borders of the wound steadily progresses, advancing by degrees into the wound, and taking the place of the blood coagulum which is present (Fig. 237). In cases of pronounced inflammatory infiltration of the borders of the

wound the old tissues in the immediate neighbourhood are more or less completely destroyed by fatty degeneration. On about the third day the wound, or the wound cleft, will be found filled with a tissue consisting almost exclusively of round cells, with a very small amount of intermediate substance, while here and there are scattered the remains of the blood coagulum. Later on there will be found large epithelioid cells (Figs. 238, 239), the actual formative cells of the granulation tissue or cicatrix—fibroblasts as they are called—which change into the fibrils of the fibrillar connective tissue (Fig. 239, *a*).

FIG. 238.—Wound in the kidney on the fourth day. Large formative cells, varying in shape (*b*). *a*, Extravasation of blood, with here and there masses of protoplasmic formative material (*c*) produced by a fusion of the white blood-corpuscles.

I used to believe that these formative cells were direct descendants of the emigrated white blood-corpuscles, but recent discoveries have forced me to abandon this view as incorrect, and I have come to the conclusion that Thiersch, Recklinghausen and others are right in stating that the original fixed connective-tissue cells and the endothelium of the vessels are the essential factors in the formation of the cicatrix. Ziegler has also recently adopted this view. The numerous nuclei in different stages of division which can be demonstrated in the fixed connective-tissue cells and the endothelium of the vessels as the latter undergo rapid proliferation are proofs of the correctness of this theory. The newly formed tissue cells can also become wandering cells. The regenerative processes within the injured organs are likewise carried on by the fixed tissue cells. The connective-tissue cell always gives rise to a new connective-tissue cell, an epithelial cell to an epithelial cell, but a connective-tissue cell is never formed from an epithelial cell, or *vice versa*. The leucocytes present either perish—i. e., are either absorbed by the growing tissue cells, particularly the polynuclear leucocytes—or they wander back into the circulation as in inflammation. On the other hand, I believe that some of the protoplasm of the wandering cells is

employed as cell material in both the scar formation and the regenerative processes carried on in the original fixed tissue cells of the neighbourhood. I am unable to say whether the white blood-corpuscles can themselves form fibrillar connective tissue when the circulation is sufficiently active, for example, in a granulating wound of granulations, but their importance in this respect is much less than that of the fixed tissue cells—i. e., the cells of the connective tissue and the endothelium of the vessels which have been demonstrated to be the real producers of the scar and are called fibroblasts. Reinke and others believe that further development is possible in those wandering cells which make their appearance after the proliferation of the fixed cells has begun, and which exhibit great vital energy. Ribbert considers it probable that the lymphogenic leucocytes with a single nucleus are capable of taking part in the construction of new connective tissue by helping to cover over the lymph cavities and spaces with endothelium.

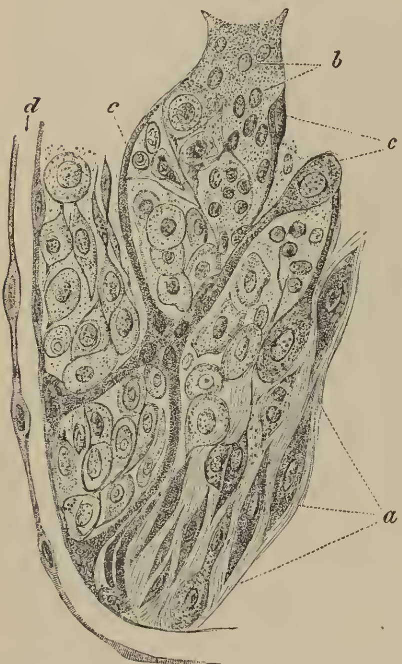


Fig. 239.—Fifth day; a piece of hardened liver with a defect in the middle; large formative cells which have developed from fixed tissue cells; *a*, clearly defined fibrillary connective tissue formed from cells; *b*, masses of protoplasmic formative material with commencing differentiation seen by the appearance of larger nuclei; *c*, solid sprouts from the vessels; *d*, blood-vessel.

New Formation of Tissue according to Ziegler, Marchand, Tillmanns.—Ziegler was the first to make an exhaustive study of the manner in which new tissue—the fibrillary connective tissue—is formed. He fitted together two pieces of glass, about ten to twenty millimetres long and ten millimetres broad, and made them adherent to each other at the corners with porcelain cement, leaving an empty space, accessible by capillarity from the sides, into which the white blood-corpuscles and the lymphatic fluid could penetrate after the glass plates had been placed beneath the skin or periosteum or inside one of the cavities of the body of an animal. The plates were left in place inside the animal from ten to twenty-five to fifty days, and when removed were gently washed, and then placed for two days in a 0·1 per-cent. solution of hyperosmic acid, after this in spirits of glycerine, and finally in pure glycerine. My own method consists in hardening in absolute alcohol pieces of lung, liver, and kidney, measuring about one cubic centimetre, and mak-

ing holes and notches in them, and then placing them with every antiseptic precaution in the peritoneal cavity of a rabbit. Sections are afterwards cut from these specimens, and when examined under the microscope will give a very beautiful picture of the new formation of tissues. Ziegler came to the conclusion that the emigrated white blood-corpuscles undergo further development, and form fibrillar connective tissue if there is a sufficient circulation of lymphatic fluid, and especially if enough nutrition is supplied by the development of new vessels. Ziegler has also, like myself, modified this view. We now know that in Ziegler's glass plates, and in my pieces of dead tissue, the new tissue is chiefly developed from the cells of the newly formed vessels. Salzer has also made recent investigations upon the healing up in a wound of foreign bodies, and Marchand particularly has made some very valuable experiments both in the healing in of foreign bodies and in the new formation of tissue. Marchand employed chiefly bits of sponge, cork, elder-wood pith, and pieces of lung and liver injected with blue gelatine, which he buried in the peritoneal cavities of guinea-pigs and rabbits. After four to seven hours a development of a network of fibrin and an emigration of numerous leucocytes took place. After twenty-four to thirty hours, and later, the foreign body became intimately connected with the peritonæum, and within it were found new cell-forms derived from the fixed elements in the neighbourhood, these cells being mostly spindle-shaped, with large, elongated nuclei, though round cells are also present. All these cells spring from the endothelium of the peritonæum, the fixed connective-tissue cells, and the cells of the walls of the vessels, etc., in which the nuclei are seen forming variously shaped figures in the process of their segmentation. There are also present giant cells, often having an extraordinary number of nuclei. The giant cells are formed by the fusing together of fixed tissue cells, and possess the power of absorbing leucocytes ; but they exhibit no progressive development, and later on perish by fatty degeneration. Giant cells are only found in those foreign bodies (bits of sponge, elder pith) whose absorption presents difficulties; and Marchand did not discover them in the pieces of lung, as the tissue of which it consists is readily destroyed, and can be absorbed by the leucocytes. The granulation cells are likewise the offspring of the fixed tissue cells, and not of the single or polynucleated leucocytes. Moreover, the offspring of the fixed tissue cells very often become wandering cells. Marchand saw segmentation figures in the nuclei of the mononuclear leucocytes. The polynucleated leucocytes develop from those with a single nucleus, and are retrogressive in nature. The leucocytes take no part in the formation of new tissues, but they do take part in the formation of fibrin which, according to Marchand, is produced by substances liberated by the death of the white blood-corpuscles. (See also page 250.)

Sherrington and Ballance maintain that the cicatrix is formed from the cells of the plasma, these cells being supplied with nourishment by the protoplasm of the white blood-corpuscles.

The Formation of Fibrillar Connective Tissue.—Ziegler's and my own experiments show that the fibrillar connective tissue—or, in other words, the cicatrix—is formed from the fibroblasts in the following way: The formative cells are at first round, and then enlarge, and look

like large, round epithelium; or they are more elongated, or possess one or more processes, some becoming spindle-shaped, others club-shaped; or they may form branching cells or polynuclear giant cells. The processes repeatedly anastomose with one another. The number of the large formative cells then rapidly increases, and in certain localities they lie close together. The fibrillar tissue is formed in part directly from the protoplasm of the formative cells, and is consequently intracellular in its origin, or it comes from a homogeneous intercellular ground substance or stroma which has previously developed from the formative cells. In the intracellular fibre-formation fibres make their appearance on one or both sides of a cell, or at one extremity of it, or in a process, and unite with the fibres of the adjoining cells. The nucleus, together with a portion of the protoplasm of the formative cell, persists as a fixed connective-tissue cell (Figs. 239, *a*, 240). The direction taken by the fibres is usually the same over a considerable area, the formative cells playing no part in determining the direction of the fibres. As illustrated in Fig. 240, the cicatrix is in the beginning rich in large elongated cells, the remains of the earlier formative cells, which in part become changed

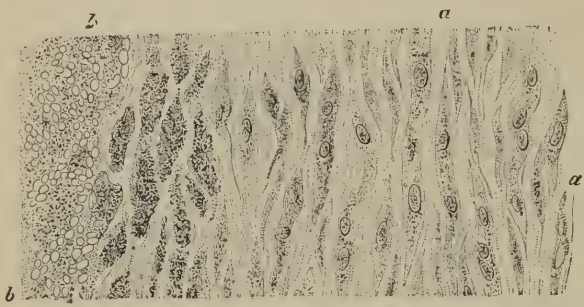


Fig. 240.—Wound in the liver in the stage of cicatrisation, tenth day. *a*, Young cicatricial tissue; *b*, liver tissue which has partially undergone fatty degeneration in the neighbourhood of the cicatrix, and contains many red and white blood-corpuscles.

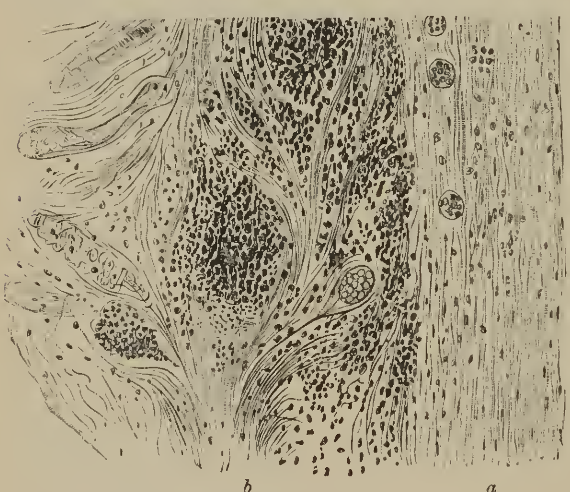


Fig. 241.—Fourteenth day; cicatrised defect (*a*) in a piece of dead, hardened lung (*b*); the latter is filled with numerous wandering and formative cells, especially in the neighbourhood of the defect, or rather the cicatrix.

into fibres. The size of these cellular remains subsequently diminishes, the fibrous tissue becomes thicker, and the cicatrix is complete (Figs. 241, 242, 243).

New Formation of Vessels.—The formation of new vessels proceeds hand in hand with the above-described tissue formation. In fact it is

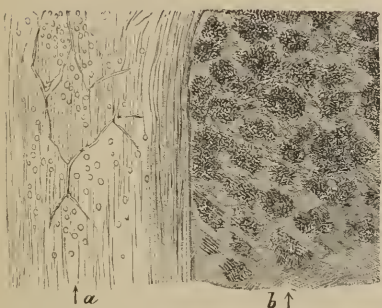


Fig. 242.—Seventeenth day; cicatrised defect (*a*) in a piece of a dead, hardened liver (*b*).

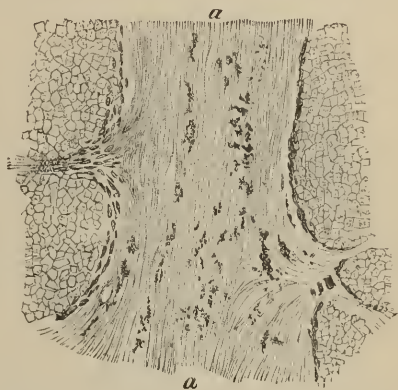


Fig. 243.—Twenty-eighth day; healed wound in the liver, cicatrix (*a*) containing blood pigment.

this that renders possible the further development of the accumulated formative cells; and the cells of the newly formed vessels also contribute very essentially to the formation of the new tissue which makes up the cicatrix.

In the earliest stages in the repair of a wound, the formative cells, or the cells of the granulation tissue, receive their nutriment from the stream of plasma escaping from the vessels in the neighbourhood. As Thiersch has shown, this intercellular circulatory system can be injected through the blood-vessels. But this arrangement for supplying nutrition to the cells is only temporary, and the formation of new blood-vessels is required for the further process of repair in a wound.

The development of new blood-vessels is the result of an actual sprouting from the walls of pre-existing vessels (Figs. 239, 244, 245). There is first noticed on the external surface of a capillary loop a granular accumulation of protoplasm, which gradually enlarges (Fig. 244, *a*, *b*, *c*) and grows into a solid protoplasmic filament, which contains a nucleus. This protoplasmic filament, simple (Fig. 244, *f*) or branched (Fig. 244, *d*, *e*, *g*), joins either with the wall of another vessel, or unites with another similar sprout advancing in the opposite direction and springing from another similar capillary loop (Fig. 244, *d*, *f*, *g*). There are also formed, not infrequently, protoplasmic filaments which turn

back in an arch to the same vessels from which they started. Furthermore, processes from the spindle- or club-shaped or branching formative cells of the intercapillary tissue join with the sprouts from the walls of the vessels, and thus the material in the formative cells helps in the formation of the new blood-vessels. After a certain length of time the originally solid protoplasmic filaments become hollow from liquefaction of their interior, giving rise to an open communication with the mother vessels,

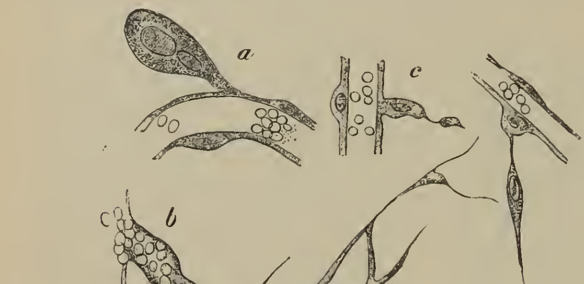
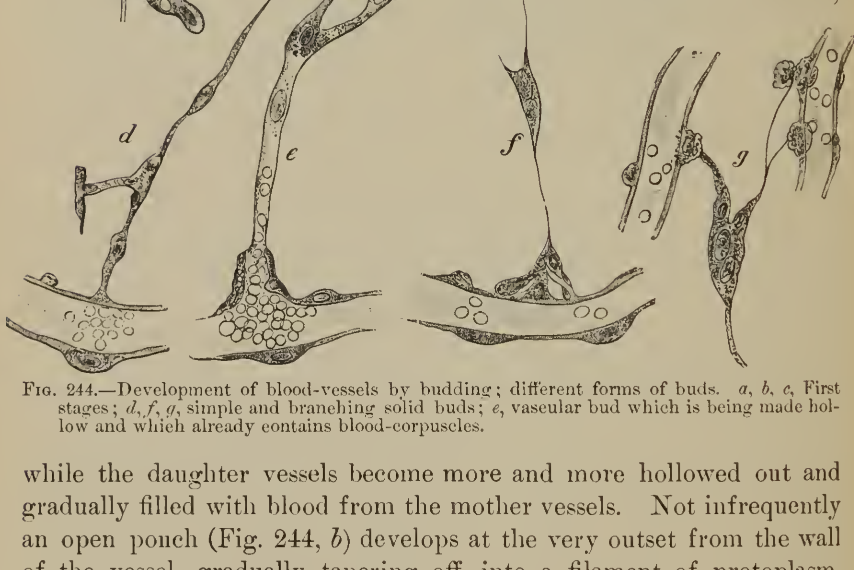



FIG. 244.—Development of blood-vessels by budding; different forms of buds. *a*, *b*, *c*, First stages; *d*, *f*, *g*, simple and branching solid buds; *e*, vascular bud which is being made hollow and which already contains blood-corpuscles.

while the daughter vessels become more and more hollowed out and gradually filled with blood from the mother vessels. Not infrequently an open pouch (Fig. 244, *b*) develops at the very outset from the wall of the vessel, gradually tapering off into a filament of protoplasm. The walls of the daughter vessel, the newly developed capillary, are at first homogeneous, later on nuclei are added, and they take on a plainly recognisable cellular structure, consisting of flat cells (endothelial cells). Subsequently the walls of the vessel are strengthened materially by the formative cells in the neighbourhood.

The above-mentioned protoplasmic filaments shooting out from the walls of the vessels are made up partly of the cells of the vessel walls, and partly, as I believe I have observed, of white blood-corpuscles which have passed through the capillary wall. At a later period a shrinkage takes place in the newly formed connective tissue of the

cicatrix, and a portion of the vessels disappear, causing the original red scar to become pale.

The manner in which the wound, or rather the granulating surface, is covered with skin, has been briefly stated above. For the purpose of healing up large granulating surfaces, Réverdin employed the transplantation of small particles of skin. This method of skin transplantation was, however, first made a useful procedure by Thiersch (see § 42). The adhesion, or rather the union, of a piece of skin on to its new bed takes place, according to Thiersch, by the vessels in the granulations and in the bit of skin becoming connected through the intercellular passages; these passages conduct the blood circulating in the granulation vessels directly into and back from the vessels in the pieces of skin. There is subsequently a formation of permanent vessels which supplants this provisional circulation. My own experiments, and those of Ziegler, show that there is at the outset a rapid emigration of white blood-cells accompanying the union or adhesion of the transplanted bit of skin. But the leucocytes are of no importance in the final taking root of the transplanted skin, the actual accomplishment of which is brought about by the fixed tissue cells, the newly formed vessels, and their cells. The minute phenomena which take place during the taking root of a Thiersch skin graft are practically the same as in any union by primary intention. The surface of the wound and the adhering layer of skin are filled with round cells. This round-celled infiltrate is then gradually changed into granulation tissue, accompanied by the sprouting of the vessels on the surface of the wound, and finally the granulation tissue becomes fibrillar connective tissue. The transplanted skin flap is at the outset passive, but from the third day on it becomes vascularised by sprouts from the vessels on the surface of the wound.

Fig. 245.—Development of new blood-vessels by budding. Seventeenth day. Wound in the liver.

In spite of this two days' interruption in the circulation of the blood, the majority of the tissue elements in the cutaneous graft retain their function and vitality, and only the epidermal layer, with a portion of the rete Malpighii, and the greater part of the vessels, will be found to perish, the latter by atrophy and hyaline degeneration. From the third or fourth day on the graft takes an active part in the process of healing into its new bed, as the epithelial cells (in the transversely cut hair follicles and excretory ducts) which lie upon the exudate proliferate and make their way into the bed. Garré says that fourteen days after the transplantation all the granulation tissue has become replaced by connective tissue, and the healing is complete.

Reunion of Entirely Severed Portions of the Body.—Parts which have been completely severed from all their connections with the body may again become united in the same manner as the skin grafts of Réverdin and Thiersch. But this is only possible in the case of small portions of tissue, such as the tip of the nose or of the fingers. To these phenomena belong the reposition of teeth which have been extracted, the transplantation of living or dead bone or cartilage into defects in bone, etc. The success of all these operations is dependent upon the strictest observance of the rules of asepsis. The transplantation of the various tissues above mentioned has been described on page 143.

The Formation of a Cicatrix in a Vessel, or the Organisation of a Thrombus.—The formation of a cicatrix in a vessel which has been wounded or ligated, or, in other words, the *organisation of a thrombus*, is of special importance.

The following is a brief description of the manner in which the thrombus forms in a vessel : Since Brücke made his famous experiments, we know that the blood is kept fluid within the walls of the vessels because of its contact with a normal endothelium, and because of its constant movement. If either one of these two conditions is lacking, if the integrity of the endothelium of the vessels is altered in any way by an inflammation or traumatism, if the blood escapes from the walls of the vessels, or if its circulation is interrupted —for example, by ligation of the vessel—the blood will then coagulate; it will form a thrombus.

The thrombus which develops after ligation of an artery, for example, extends from the point at which the ligature has been applied to the nearest lateral branch above and below. The same holds true as regards the veins. We know, however, that in a vein extensive thrombi form much more readily than in an artery, and this is the case not only when the lumen is occluded by a ligature or an injury, but also when there occurs a pronounced stasis and obstruction to the forward movement of the blood. If two ligatures are applied to a vessel with a moderate interval between them, the blood will coagulate between these ligatures; but a thrombus does not always develop after the ligation of a vessel. Baumgarten demonstrated that the blood

lying between two ligatures may remain fluid for three, four, or even twelve to fifteen days if the ligation is carefully performed, and particularly if the wall of the vessel is not isolated from its connections with the adjoining tissues, and if its nutrition from the vasa vasorum is not interfered with. Under such conditions the endothelium appears to remain intact and performs its functions normally, and consequently the blood, though not moving, retains its fluid character.

In wounds or injuries involving only a portion of the circumference of a vessel there is not always the formation of a thrombus filling the entire lumen of the vessel. The rent in the wall is often completely filled by a thrombus which organises, leaving only a thickening of the vessel at the site of the injury. This method of repair may take place in vessels of any size whatsoever. Again, a thrombus which at the outset only partially fills the lumen may finally cause its total occlusion by the addition to it of one layer of coagulum after another.

We have to deal mainly with thrombi occurring after an injury or the ligation of a vessel. Mention should also be made of the so-called compression thrombi, which form when the blood is brought to a standstill as a result of compression from without, as by tumours; of the dilatation thrombi in aneurysms and varices; of the thrombi caused by inflammatory processes in the walls of the vessels accompanied by destruction of the endothelium, etc.

But changes in the walls of the vessels and primary disturbances in the circulation are not always sufficient in themselves to produce coagulation of the blood; the cause for the thrombosis must be sought for not infrequently in a general alteration in the composition of the blood. Silberman has seen multiple coagula form during life from acute poisoning by the salts of hydrochloric acid, arsenic, phosphorus, and several other blood poisons. On the other hand, Arthus proved that by depriving the blood of its calcium it loses its power of coagulation.

Red, White, and Mixed Thrombi.—There are red, white, and mixed thrombi. The formation of a white thrombus by an accumulation of white blood-cells can be watched under the microscope by irritating with a crystal of common salt placed in its neighbourhood, some large artery or vein lying in the spread-out mesentery or tongue of a curarised frog. At the point of irritation the inner wall of the vessel becomes covered with white blood-corpuscles, and a white immovable plug gradually develops, filling the entire lumen of the vessel by a constant addition of new white corpuscles to those already in place. Some investigators claim that the white thrombi described by Zahn are not formed from white blood-corpuscles, but from the blood plaques discovered by Bizzozero, those very small, delicate, colourless, disk-shaped bodies which constitute the third formed ingredient of the blood. The origin of the blood plaques, which can be stained with methyl violet while in a neutral common-salt solution, is still obscure, and their significance is still a matter of controversy. Eberth and Schimmelbusch make a sharp distinction between the white thrombi of blood plaques and the red blood-clots; the blood plaques, according to these authorities, having nothing to do with the formation of fibrin, and simply adhere together at some injured point of the intima as a result of their peripheral location in the blood stream when there is any marked retardation in the flow of the current.

They also hold that a thrombus is not identical with a blood coagulum, the thrombi being not red, like the ordinary coagulum, but either entirely, or for the most part, white.

Coagulation of the Blood.—There are many views as to the manner in which coagulation of the blood takes place. Alexander Schmidt and his followers, reasoning from numerous experiments, explain coagulation of the blood in the following manner: The fibrin results from the union of two fibrin generators, the fibrinogen and the paraglobulin, brought about by the action of the fibrin ferment. The fibrinogen exists in solution in the blood plasma; the fibrin ferment and the paraglobulin are first liberated by the disintegration of the white blood-corpuscles, and then have the power of acting upon the fibrinogen. As long as the white blood-corpuscles circulate uninjured in the blood a coagulum cannot form. In the blood of birds and amphibia the disintegrated red (nucleated) corpuscles furnish the fibrin-making substances. The blood in immediate contact with the living and normal walls of a vessel, as we have said, does not coagulate; but if the walls are altered by pathological processes or mechanical injury—if, for example, the intima becomes changed by inflammation, if it becomes roughened, uneven, swollen, torn, etc.—a blood-clot will form at these points even while the circulation still continues. Blood which has escaped from a wounded vessel will immediately coagulate, as will blood within the heart or a vessel after death. Moreover, by the disintegration of white blood-cells which takes place under normal circumstances in healthy, circulating blood, some fibrin ferment develops (Schmidt, Jakowicki, Birk); this is the case especially in venous blood. It is furthermore an interesting fact that in septicæmia and pyæmia the amount of the fibrin ferment resulting from the disintegration of the white blood-corpuscles can be so increased as to give rise to the spontaneous formation of coagula (Köhler and others). On the other hand, fever is produced (Wahl, Bergmann, Angerer) by the absorption of the fibrin ferment from the extravasated blood after operations or subcutaneous injuries (fractures).

Bizzozero, on the other hand, ascribes the formation of fibrin solely to the dissolution of the blood plaques and their derivatives (Zimmermann's corpuscles), and he denies that the white blood corpuscles have any part in the process. Haym also claims that the cause of the coagulation of the blood when a vessel is injured is to be sought for in what he calls the "hæmatoblasts" (Bizzozero's "blood plaques"). These small, very easily altered cellular elements in the blood become immediately changed, according to Haym, when a foreign body comes into contact with them, or when the intima of the vessel loses its integrity by pathological processes or mechanical influences.

Wooldridge made some very exhaustive experiments upon the subject of coagulation of the blood, under Ludwig's guidance, in the Physiological Institute at Leipsic, and he states that Alexander Schmidt's explanation of coagulation of the blood is correct only to a very limited extent, if at all. Wooldridge disputes the necessity of the co-operation of the formed elements of the blood in the process of coagulation, and asserts that the blood plasma itself, free from all formed elements, contains everything which is necessary for the production of coagulation. The plasma is caused to coagulate by two

bodies contained in it, which are a combination or mixture of albumen and lecithin, and are called by Wooldridge A- and B-fibrinogen. He states that certain substances (albuminous bodies containing a very large percentage of lecithin) which have a marked power of producing coagulation can be isolated from the testicle, lymph glands, the chyle, brain, thymus, and stroma of the red blood-corpuscles. He does not attach any importance to the fibrin ferment as a cause of coagulation.

Our knowledge of the coagulation of the blood has been recently enriched by some exceedingly interesting facts discovered by the important investigations made by Marcus Arthus.* Arthus found that by the addition to the blood of oxalate of ammonia—i. e., by decalcification of the blood—the latter loses its power to coagulate; but if chloride of calcium is again added in excess the blood then immediately coagulates. From this it follows that the calcium in the blood has a fibrinoplastic action, and that the fibrin ferment and the fibrinogen only act in the presence of calcium salts. Arthus states that the salts of strontium have the same effect as those of calcium, and consequently there is also a strontium fibrin. This makes it necessary for us to recognise many different kinds of fibrin. Arthus maintains that the teachings of Schmidt and Hammerstein should be modified to the extent of making three factors necessary for the coagulation of blood, viz., the fibrin ferment, fibrinogen, and a lime salt. According to Arthus, the coagulation of the blood is analogous to the coagulation of cheese from milk, the caseine corresponding to the fibrinogen, the curdling ferment to the fibrin ferment, and the cheese to the fibrin.

Freund maintains that the coagulation of the blood is brought about by the undissolved phosphate of calcium. The phosphates and potassium salts preponderate in the blood-corpuscles, the sodium and calcium salts in the serum. When the blood comes in contact with a foreign body and ceases to touch the walls of the vessel, the phosphates in the blood-corpuscles unite with the calcium salts in the serum, forming a large amount of phosphate of calcium, which does not all remain in solution.

The Varying Reaction of the Leucocytes to Staining Substances.—The colourless blood-corpuscles (leucocytes) vary in their reaction to staining materials—a matter of great diagnostic importance (Ehrlich). While the nuclei of all leucocytes are coloured by the well-known aniline dyes used for staining nuclei, the protoplasm of the cells behaves differently, possessing for particular dye stuffs a greater or less affinity. The leucocytes differ also in size and in the number of their nuclei (mono- or polynucleated). The majority of the leucocytes (about seventy per cent. of the colourless blood-corpuscles) form the polynucleated leucocytes, the granules in which are neutral (neutrophilar)—i. e., their protoplasm is only susceptible of being stained by neutral dyes, such as, for example, a neutral mixture of a basic and acid aniline dye (methylene blue and the so-called acid fuchsin). A smaller number of the leucocytes (about five per cent. to eight per cent.) in the blood are eosinophilar or acidophilar cells—in other words, the granules of their protoplasm are capable of being stained bright red by the acid dye eosin. The acidophilar

* Marcus Arthus. Thèses presentées à la faculté des sciences de Paris. Paris: H. Jouve, rue Racine, 15.

or eosinophilar granules are coarser than the neutrophilar ; the cells also are perceptibly larger than the neutrophilar, and for the most part possess one or two nuclei of considerable size. The third class of leucocytes, which are rare —mostly mononucleated cells—possess a protoplasm which is only capable of being stained by basic aniline dyes (basophilar leucocytes). The fourth class of leucocytes, mostly small mononucleated cells with a narrow or broad enveloping band of protoplasm, are partly neutrophilar and partly capable of being stained by acid as well as basic aniline dyes (amphophilar). Mosso* has made an exhaustive study upon the change of the red blood-corpuscles into leucocytes and the necrobiosis of the red blood-corpuscles in coagulation and suppuration.

Changes in the Thrombus.—After a thrombus has formed, the further points in its history which are of interest are (1) its organisation into solid connective tissue containing blood-vessels, or, in other words, the formation of a cicatrix, and (2) the softening of the thrombus. The organisation of the thrombus into connective tissue containing vessels is the most desirable termination ; but softening of the thrombus, particularly its suppurative breaking down, brought about by the action of bacteria and accompanied by subsequent embolic processes, is always dreaded by the surgeon. Thanks to the aseptic method of operating and treating wounds, this infectious softening or breaking down of a thrombus is of infrequent occurrence in modern surgery. We shall treat of the infectious softening of thrombi more in detail when we come to diseases of wounds. The calcification of a thrombus from deposition of lime salts is another comparatively satisfactory change which a thrombus may undergo. The so-called phleboliths are calcified thrombi which have formed in veins.

FIG. 246.—Organisation of a thrombus; *M*, media infiltrated with cells; *J*, intima infiltrated with cells; *B*, various shaped formative cells resulting from the proliferation of the endothelial cells of the vessels and employed in the organisation of the thrombus (formation of the cicatrix in the vessel); *Th*, thrombus. × 300.

Organisation of the Thrombus, or rather the formation of a Vascular Cicatrix.—We are here concerned with the question of the organisation of the thrombus into connective tissue containing vessels, and in the formation of a vascular cicatrix.

* Virch. Arch., Bd. 109, 1887.

The minute changes are practically the same as we have described above, and they apply to the arteries as well as the veins. According to Thiersch, Thoma, and others, the closure of a vessel, the so-called organisation of the thrombus, or, more correctly, the substitution for the thrombus of connective tissue, is mainly brought about by a proliferation of the endothelium of the intima. All the authorities agree that the thrombus itself plays no part in the formation of a cicatrix in a vessel; it is gradually supplanted by the cellular infiltration, which then forms fibrillar connective tissue. At first variously shaped formative cells (Fig. 246) develop by the proliferation of the endothelium of the vessels, and these subsequently change into fibrillar connective tissue. These cells penetrate the thrombus in all directions; the connective tissue developing from them becomes steadily stronger, and finally takes the place of the thrombus throughout its whole extent. At the conclusion of the process there only remains of the thrombus a few granular masses of brown pigment—hæmatogenous pigment, probably hydroxide of iron. Simultaneously with this endothelial proliferation and growth of cells into and throughout the thrombus the latter becomes vascularised by the formation of new vessels. If a thrombus does not completely occlude the lumen of a vessel, its organisation takes a longer time than when the vessel is completely plugged by the thrombus (Baumgarten). The cicatrix is formed from the cellular germinal tissue in the manner we have described on page 286. The vascularisation of the thrombus—i. e., the formation of new vessels within it—takes its start chiefly from the point at which the intima has been broken or torn. The vasa-vasorum, on account of the diminution of the pressure in the interior of the vessel, grow through the relaxed walls into the lumen of the vessel (Benecke, Ackermann).

The minute changes which take place in the organisation of a thrombus can be studied very satisfactorily by placing, with every antiseptic precaution, a segment of a vessel which has been previously hardened in absolute alcohol inside the peritoneal cavity of a rabbit (Seuftleben, Tillmanns). There will be observed a steadily increasing emigration of colourless blood-corpuscles into the wall and interior of the vessel, or rather into the thrombus; at the same time there will be a corresponding new formation of vessels from the germinal cellular tissue, which is developed from the endothelium of the newly formed vessels and not from the white blood-corpuscles, and finally the thrombus becomes supplanted, in the manner already described, by vascular fibrillar connective tissue, and the vessel is closed by a cicatrix (Fig. 247).

The length of time required for the cicatricial closure of a vessel to take place by the organisation of a thrombus varies very much. In young subjects the reparative process is in general more rapid than in

old individuals, and it is slowest in the case of patients afflicted with chronic (atheromatous) degeneration of the intima of the vessels. In animals which have been experimented upon, vascular tissue will be found at the site of the thrombus, or rather where the ligature has been applied to the vessel, at the end of the second week, and possibly even earlier, by the seventh to the eighth day. During the third to the fifth week the cicatrix in the vessel becomes completely formed, though in some cases the process takes much longer. In course of time the cicatrix in a vessel shrinks like any other scar. If the cicatrix shrinks in the centre, the scar, or rather the vessel, may again become pervious, so that the final result may be merely a diminution in the lumen of the vessel, with a thickening of its wall. In still other cases the cicatrix, as a result of dilatation of the vessel in which it lies, may become perforated by several small isolated vessels connecting the central and peripheral ends of the artery (Fig. 249). The so-called sinus degeneration (Rokitansky), in which the thrombus is changed into a network of connective-tissue strands having spaces between them, is particularly liable to occur in thrombi which develop in veins.

FIG. 247.—Organised vascular thrombus in a piece of dead kidney. Nineteenth day. In the centre are a newly formed blood-vessel and a giant cell. The adventitia of the wall of the vessel contains many leucocytes, but the muscular coat not so many. Gentian, Canada balsam.

Collateral Circulation.—If a blood-vessel—an artery, for example—is occluded at some point by a ligature or a thrombus, a collateral circulation is immediately developed by dilatation of the vasa vasorum and of the branches given off on the proximal and distal side of the thrombus. This restores the circulation, and ensures the nutrition of the portion of the body supplied by the occluded artery (Fig. 248). It is interesting to note the manner in which the collateral circulation becomes established after ligation of an artery in its continuity, as illustrated in a specimen obtained by Luigi Porta, showing the collateral circulation eight months after ligation of the abdominal aorta in a dog (Fig. 249).

It is plain that the collateral circulation took place in this instance both through the dilated vasa-vasorum lying between the two stumps of the ligated aorta and the adjacent lumbar arteries, and branches made up partly of old and partly of newly formed vessels.

Recently Nothnagel has made some very exhaustive experiments on rabbits relating to the establishment of the collateral circulation, and he found that six days after applying the ligature there occurred a hypertrophy and hyperplasia of the muscular fibres in the dilated collateral arteries. Nothnagel and Recklinghausen explain the growth of these vessels by the increased rapidity of the blood current within them and the increased amount of nutrition which this brings about. The

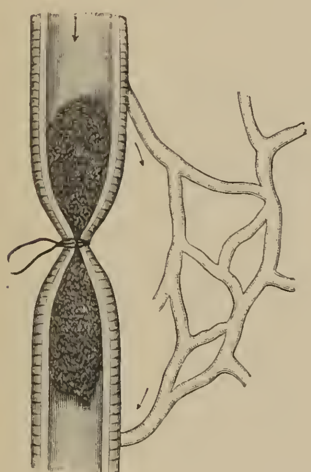


FIG. 248.—Collateral circulation (after ligation of an artery in its continuity) through the central and peripheral branches.

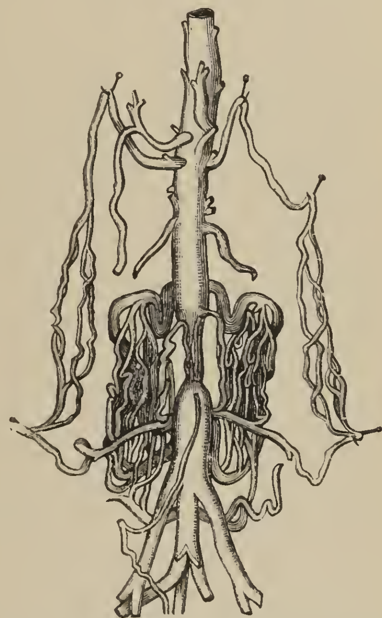


FIG. 249.—Collateral circulation eight months after ligation of the aorta of a dog (Porta).

more blood that passes through a vessel in a given time, the greater is the amount of nutritive material supplied to the wall of the vessel. The pressure theory, which many authorities think sufficient to account for the establishment of a collateral circulation, is, according to Nothnagel, of no value.

The repair of a Wound in Non-vascular Tissues.—The process of repair in a wound, or the formation of a cicatrix in tissues which do not contain vessels (cornea, cartilage, etc.), is practically the same as for vascular tissue. We know that non-vascular tissues—the cornea, for example—contain an intricate communicating system of canals, in which, under normal conditions, wandering cells are present here and there.

If the cornea is injured there occurs an abundant emigration of white blood-corpuscles from the adjoining sclera and conjunctiva and from the conjunctival sac. The tissue developed from the inflammation—in other words, the cicatrix—is here also formed from the original fixed cells of the cornea.

A cicatrix is formed in cartilage in precisely the same way from the cartilage cells in the neighbourhood. The cicatrix resulting from an aseptic wound—i. e., from one which has healed without reaction—will retain its fibrillar character for a great length of time. Gies claims that it retains this character permanently; but if a severe inflammatory reaction takes place the cicatrix will rapidly become hyaline, like normal hyaline cartilage (see Injuries of Joints).

Regeneration of Injured Tissues.—In every injured organ there is always an attempt to bring about, as far as possible, a complete *restitutio ad integrum.* The regeneration of the damaged tissues will take place the more rapidly and completely the more delicate the cicatrix is—in other words, the stricter the asepsis and the more the wound is made to heal by primary union without reaction, and the less the cells peculiar to the organ are damaged. But the more highly organised tissues have relatively slight powers of regenerating themselves after they have been damaged. The epidermis, the epithelium of the mucous membranes, bones, cartilage, periosteum, tendons, and other connective-tissue structures, are capable of regenerating themselves completely, while, on the other hand, losses of substance in the various glands and in muscle are not restored, but their place is supplied solely by scar tissue, in the manner described above. Consequently, a cicatrix which includes the more deeply lying subcutaneous cellular tissue contains no sweat or sebaceous glands and no hair follicles or hairs, and a correspondingly extensive cicatrix in the intestine contains no follicles and no glands of Lieberkühn. Moreover, defects or losses of substance in muscular tissue are only made good, as already stated, by scar tissue, and are not replaced by newly formed muscular fibres; the fibrous cicatrix is interposed like a tendinous intersection in the course of the muscle and enables it to contract. Regeneration of muscular fibre takes place only in the neighbourhood of the cicatrix, and in those cases in which the injury to the muscle has been trifling—a contusion, for example. Ponfick, however, has demonstrated that losses of substance in highly organised tissues, such as the liver and kidneys of animals, can be made good in a relatively brief time by a new development of the tissues characteristic of the organ.

Of the more highly organised tissues the peripheral nerves are exceptional as regards their capability of regenerating themselves. After

a nerve has been divided and neurorrhaphy performed, there will often be a complete regeneration of the nerve even when the neurorrhaphy has been performed several months, or even a year, after the reception of the injury. Regeneration has been brought about in a nerve in which there has been a loss of substance several centimetres in length by suturing together the divided ends of the nerve, or by adopting other suitable measures, and now and then even spontaneously. I performed a successful neuroplasty upon the median and ulnar nerves for a loss of substance which they had suffered several months previously (see § 88).

Regeneration of the tissues of the brain and spinal cord never takes place in man, though Brown-Séquard has seen regeneration occur in the divided spinal cord of a pigeon.

The proper treatment for promoting regeneration in the various tissues will be discussed in §§ 87, 88, 101.

Subsequent Pathological Changes in the Cicatrix—Cicatricial Contraction. —*Cicatricial contractures* are the most important of the later pathological changes which scars undergo. The contraction is, of course, proportionate to the size of the defect or the amount of granulation tissue. All cicatrices replacing losses of substance in the skin and the underlying tissues are especially liable to shrink. According to the depth to which the loss of substance extends, the cicatricial contracture involves only the skin, or, besides this, the deeper parts, especially the fascia, muscles, and tendons. The cicatricial contractions following extensive burns are especially dreaded. The sequelæ of such contractures vary with the locality which is affected. If one is situated on the flexor aspect of a joint, the latter will become fixed in a certain degree of flexion and cannot be completely extended. Cicatricial shortening of the sterno-mastoid muscle causes wry-neck (caput obstipum); a scar involving the under eyelid will roll the latter outward (ectopion); cicatricial contracture of the cheek will interfere with the opening of the mouth. The chin and neck are sometimes fastened firmly together as a result of burns. This is not the place to describe the treatment for these conditions, and it is only necessary to state that they are now treated with excellent results by methods of gradual extension, or by excision of the scar, followed by implantation of Thiersch skin grafts, or of flaps with pedicles taken, perhaps, from a widely removed portion of the body.

Keloids.—Occasionally the cicatrix becomes the seat of a tumour-like fibrous induration called a keloid. A thick elevation develops at the site of the scar, usually with outgrowths extending into the adjoining healthy tissues. This is really a hypertrophy of the cicatrix. The cause of this keloid, which is rather rare, is not understood. After its extirpation there is usually a recurrence. I saw one case of cicatricial keloid the size of a plum, following a perforation made in the lobule of the ear, which resisted every kind of treatment with the knife and red-hot iron. Sometimes a keloid disappears by degrees spontaneously.

Malignant New Growths.—Occasionally malignant new growths, like car-

cinomata, may originate in cicatrices. We shall discuss this possibility when we come to the etiology of tumours.

Cicatricial Ulcers.—Now and then cicatricial tissue breaks down and suppurates, giving rise to a cicatricial ulcer, which ordinarily is covered with large fungous granulations having no tendency to become covered with skin. This usually occurs in weak and sometimes in tubercular individuals, and is apt to start from some slight injury, such as the friction produced by clothes might bring about.

Pressure Paralysis of Nerves from Pressure of the Scar.—A large cicatrix may exert injurious pressure upon the blood-vessels in its immediate neighbourhood, and may also cause a pressure paralysis of the nerves. It is well known that these pressure paralyses due to cicatrices have, as a general thing, a favourable prognosis, and will ordinarily quickly disappear with removal of the cause.

§ 62. **The General Reaction which follows an Injury and an Inflammation—Fever.**—The general condition of those who have been injured or operated upon bears a most intimate causal relationship to the behaviour of the wound. If the latter heals normally—i. e., aseptically—and if no injurious substances gain access from the wound to the circulating fluids of the body, there will usually be no fever. From the fact that a wound which heals aseptically, as a rule, ensures freedom to the patient from a general febrile disturbance, it follows that the febrile disturbance involving the whole system of those who have been injured or operated upon is mainly caused by the absorption from the wound of injurious substances, the most important of which are the micro-organisms and the poisonous products of their metabolism held in solution by the fluids of the body. The so-called wound fever is really an absorption fever—an alteration of the blood.

The fever which accompanies the so-called internal diseases is also in part an absorption fever, and the changes which are present in the blood and produced by the bacteria, or rather the products of their metabolism (ptomaines, toxines), play a most important part in the causation of the phenomenon. On the other hand, we must look for the cause of what is called the *essential* fevers in the central nervous system. In this latter class belong the febrile disturbances following a violent fright, the periodic stages of excitement in mental disorders, epileptic fits, injuries of the spinal cord, etc. These "nervous fevers" are perhaps caused by an increased metabolism in the tissues due to the excessive nerve irritation, which raises the temperature of the body, or to diminished loss of heat by radiation as a result of the lessened rapidity of the circulation (Murri). The fever which follows phlebotomy and the administration of cocaine is, according to Mosso, also dependent upon the nervous system. Though recent investigations have made

the etiology of wound fever so plain to us, we unfortunately are still much in the dark as regards the nature of the febrile process. The symptoms of fever are perfectly simple, but their explanation still presents many insurmountable difficulties, and allows plenty of room for many hypotheses.

We shall confine ourselves to the discussion of the fever which accompanies surgical diseases.

Symptoms of Fever.—The most important manifestations of any fever are (1) the increase in the temperature of the body, (2) the circulatory disturbances, and (3) the changed products of the metabolism of the body.

The Increase in the Temperature of the Body.—The most constant symptom of fever, and the one which is proportionate to its intensity, is the increase in specific heat. For ascertaining the temperature of the body, we use in Germany a thermometer having a scale divided into one hundred parts, and each of the one hundred parts subdivided into ten parts. The most useful is the so-called maximum thermometer, in which the column of mercury maintains its altitude after the instrument has been removed from the axilla or rectum, and readily permits at any time the reading off of the highest temperature registered. The temperature of patients who have been injured or operated upon is ordinarily taken in the axilla or rectum two to three times a day—morning, noon, and evening. But not infrequently it is important that it should be ascertained hourly, or every two hours, especially in cases with high fever, in which the height of the fever decides the kind of therapeutic measures that should be undertaken.

If the fever is slight the temperature in the axilla may amount to 38·5° to 39° C. (101·3° to 102° F.); if severe, to 40° C. (104° F.); while temperatures above 41° C. (104·1° F.) or 42° C. (106·5° F.) are called by Wunderlich hyperpyretic. Unusual rises of temperatures like this, to 42° C. (106·5° F.) and higher, are ordinarily the precursors of a rapidly approaching death. Temperatures higher than 44·5° C. (113° F.) are very rarely observed, though Phillipson has recorded the case of a girl twenty-five years old in whom the temperature reached 47·2° C. (116·6° F.). Occasionally the temperature continues rising several hours after the death of the patient (post-mortem rise of temperature). The initial stage of fever is usually characterised by a more or less pronounced feeling of chilliness or a rigour. This is the more pronounced the more rapidly the fever rises and the shorter the initial stage of the fever. A chill is usually absent if the body temperature rises gradually during several days. During the cold stage the temperature of the body is already elevated. The cold feeling is the ex-

pression of a nervous excitation caused by the difference in temperature existing between the internal and the external or superficial por-

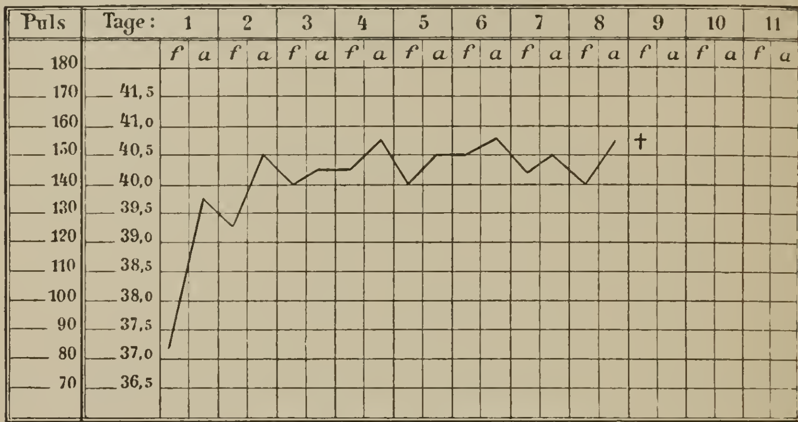


Fig. 250.—Febris continua. Death on the eighth day.

tions of the body. After the stage of cold there follows the climax—i. e., the fever reaches its maximum point. The subsequent course of the fever varies. The temperature either remains more or less continuously elevated (Febris continua, Fig. 250), or it fluctuates (Febris remittens, Fig. 251). If the fever is a continued one, the difference between the maximum and minimum rises of temperature taken in

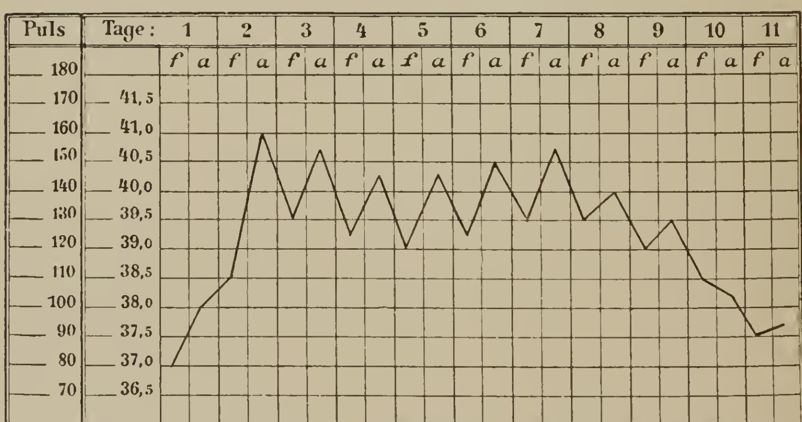


Fig. 251.—Remittent type of fever with gradual fall of temperature (lysis) from the eighth day on.

the course of the day, or morning and evening, will be at the most but a few tenths of a degree (Fig. 250). In a remittent fever there will be a daily fall of about 1° C. (1·8° F.) or more. A third type of fever

is the intermittent, in which brief marked rises in temperature alternate with normal or even subnormal temperatures (Fig. 252). After

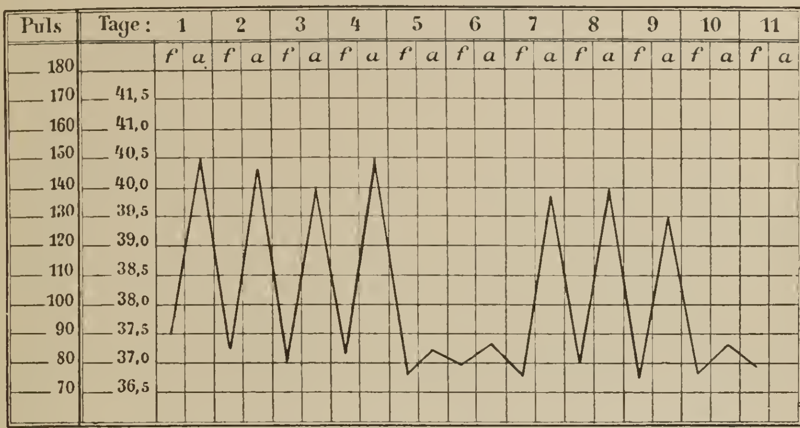


Fig. 252.—Intermittent type of fever with temporary sudden fall of temperature (crisis) on the fifth day; fresh rise of temperature on the seventh day, and then on the tenth day a sudden fall of temperature followed by convalescence.

each fall the temperature rises again in the course of the day, regularly registering higher in the evening than in the morning, or the exacerbations may occur less frequently than this. As we shall see when we come to diseases of wounds, the course of the fever is typical for many diseases, especially the way that defervescence takes place. The decline of the temperature may take place rapidly in the form of a crisis, falling 2° to 3° to 4° C. (3·6° to 7·2° F.), and even more in a few hours on a single day (Fig. 252). In such cases the temperature may drop below normal and become subnormal, sometimes accompanied by symptoms of collapse and nervous excitement (delirium of collapse). In other cases the defervescence comes on more gradually (by lysis), being for several days continuous or remittent, with transient rises (Fig. 251). The defervescence is usually accompanied by sweating. After the fall in the fever there ensues the stage of convalescence, which is frequently only simulated, as a new outbreak of the fever may take place with a set of symptoms exactly the same as those which occurred in the beginning (Fig. 252). Thus, in a protracted fever like chronic pyæmia, the fever may alternate with an apparent period of convalescence, until death or true convalescence make their appearance. When the fever has a fatal termination, death may come on during the hot stage, and is then often the direct result of the high temperature; or the cause of death is to be sought for in the general weakening of the body brought about by the fever, particularly in the degeneration of the muscles of the heart and the muscular coat of the blood-vessels,

and, above all, in the general systemic poisoning which is due to bacteria. The behaviour of the temperature curve is a most important diagnostic guide for the surgeon in his estimation of the condition of the reparative process going on in the wound, and it enables him to judge whether the dressing requires changing or not. Moreover, the surgical wound diseases, as we shall see, are characterised by a typical fever curve.

From these facts it is easy to understand the importance of carefully ascertaining the body heat in those who have been operated upon or injured.

The *other symptoms of fever* consist of disturbances in the circulation, the breathing, the digestion, and the nervous system. They occur as the result of the elevated temperature or of the primary disease.

Behaviour of the Pulse in Fever.—Great importance attaches to the condition of the pulse, as regards its frequency, tension, and regularity. Its frequency, in general, corresponds to the height of the fever, but exceptions to this rule are not infrequent; thus, for example, as the result of stimulating the vagus or its centre in the medulla, there occurs a slowing of the pulse with an elevation of the temperature. In cases of iodoform poisoning the temperature may be 38° C. (100·4° F.), while the pulse is very markedly accelerated. The state of the blood pressure is not constant in fever; ordinarily it is somewhat lower than normal (Ludwig, Hüter). If the fever remains high for any great length of time, the blood pressure becomes very decidedly lessened, and may give rise to dangerous symptoms. The pulse is often dicrotic (Fig. 252, 2)—i. e., it shows in the place of a single beat a double one, caused by a diminution of the arterial tension. A dicrotic pulse can be produced artificially in animals by injection of atropine subcutaneously or by administering amyl nitrite by inhalation (Fig. 253, 3). The rapidity with which the blood current flows, according to the measurements taken by Ludwig and Hüter with the sphygmograph, is reduced during fever about one third.

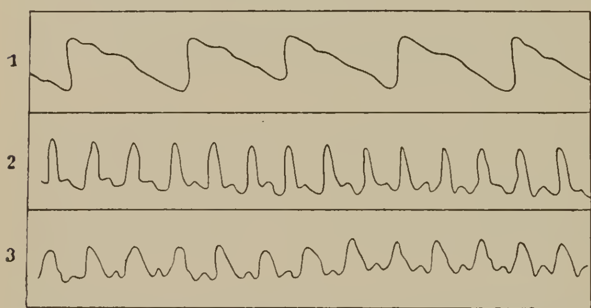


Fig. 253.—1, Normal pulse with well-marked arterial tension; 2, dicrotic, rapid pulse in fever; 3, very rapid dicrotic pulse after injection of atropine (Meuriot-Marey).

Condition of the Vessels during Fever.—Maragliano has demonstrated, with the aid of Mosso's plethysmograph, that the cutaneous blood-vessels are contracted during fever before any rise in temperature can be detected ; that, as the contraction of the vessels advances, the temperature begins to rise, and reaches its highest altitude simultaneously with the maximum of contraction in the vessels ; and that the fall of temperature is preceded by a dilatation of the blood-vessels.

Cheilo-angioscopy.—Hüter has attempted to make a microscopic investigation of the circulation of the blood in the lip of a man suffering from fever. The cheilo-angioscope, as it is called, which is used for this purpose, is described in Part I, of Hüter's Principles of Surgery. By means of this instrument he noted that in fever the circulation in the smaller vessels was retarded, and finally that the blood in them came to a standstill.

Condition of the Respiration during Fever.—During fever the respiration is more active; there is a greater consumption of oxygen, and as fever increases, or, in other words, metabolism becomes more active, there is a larger amount of carbonic acid produced. According to Kraus, twenty per cent. more oxygen is consumed during fever than when the body is in a normal condition. The respiration, particularly at the beginning of the fever, is deeper than it ordinarily is; but later on, after the fever has persisted some time, it becomes shallower, on account of the weakening of the respiratory muscles. If the fever lasts for a long time, an increase in the amount of gaseous interchange in the lungs may not take place, owing to the accompanying inanition of the patient.

Disturbances of the Nervous System.—The disturbances of the nervous system during fever vary with the height to which the temperature rises, and with the location of the injury. They consist in a feeling of general lassitude and debility, and, if the fever is high, in a dulling of the patient's intellect, accompanied by all kinds of symptoms denoting irritation and depression of the central nervous system.

Digestion.—The *digestion* is impaired during fever; there is pronounced loss of appetite; there is a diminution in the amount of the digestive juices secreted, and the peristalsis of the gastro-intestinal canal is lessened. Thirst is usually increased, and the tongue is apt to be dry.

Urine.—The *amount of urine* secreted is diminished, chiefly as the result of the lessened absorption of nutritive matter and the increased excretion of water by the skin and lungs. The urine of a patient in fever has a high specific gravity ; it is rich in nitrogenous substances, particularly urea, and in the calcium salts, and it is poor in sodium chloride. The large percentage of calcium salts and colouring matter is due to the increased disintegration of the red blood-corpuscles which

takes place during fever. Not infrequently the urine in fever contains albumen and hyaline casts.

Muscular System.—The *symptoms* referable to the *muscular system*, consisting of weakness and pain, are partly nervous in their nature, being caused, in all probability, by an altered innervation, and partly are directly dependent upon changes in the muscles consisting of a parenchymatous degeneration of their contractile substance.

Body Weight.—The weight of the body diminishes during fever, as a result of the increased metabolism or destruction of albumen. The weight which a patient loses in fever would be much greater if the destruction of fat were in the same ratio as that of albumen. According to Kraus, the fat is not destroyed in the same proportion as the albumen. Leyden has demonstrated by many systematic measurements that the loss of weight is greatest during the crisis of the fever, and in twenty-four hours at this stage the average weight lost amounts to 10·6 parts in 1,000.

Prognosis—Outcome of the Fever.—As Cohnheim has correctly stated, the body makes use of fever to destroy as rapidly as possible the noxious substances which have gained access to it. In this sense fever is advantageous to the organism. It was formerly thought that the danger in a febrile disease lay mainly in the elevation of the temperature—in other words, that death was caused principally by the abnormally great specific heat. This view is being more and more successfully contested. We know now, as regards the febrile diseases, especially those following wounds, that the species of pathogenic bacteria which may be present, or the products of their metabolism, are the principal factors in determining the prognosis of the febrile infection. The length of time which a febrile disease lasts may, aside from the severity and nature of the infection, become dangerous to the patient as a result of the increasing inanition. According to Leyden, the daily loss during fever amounts to about seven tenths per cent. of the total weight. Chossat states that all the higher animals die when they have lost forty per cent. of their weight through deprivation of nourishment; consequently a moderately severe fever would be sufficient to kill a man in about eight weeks.

The Pathological Changes during Fever.—The *pathological changes* in fever will be described under the infectious-wound diseases, and when we come to discuss those subjects we shall learn about the changes in the composition of the blood brought about by micro-organisms. It is sufficient to note here that the cloudy swelling, or parenchymatous degeneration, as it is called, of the glands and muscles, varying from a granular cloudiness and swelling to pronounced fatty degenera-

tion, used to be erroneously looked upon as the result of the high temperature. Furthermore, the loss of weight which accompanies a fever of any considerable duration is not the direct result of the fever, but of the infection or intoxication which has occurred. It is more exact to ascribe all these changes not to the increased heat of the body, but to the nature of the infection or poisoning.

Etiology and Character of Fever, particularly of Wound Fever.—If we would understand the *etiology* and nature of fever, we must attempt to give an explanation of the principal symptom of fever—viz., the rise of temperature. We have already emphasised the fact that fever is mainly the result of absorption. Billroth and C. O. Weber were the first to add materially to our knowledge of the etiology of fever, and they demonstrated that fever can be caused in animals by introducing into the subcutaneous cellular tissue, or directly into the blood, decomposing animal or vegetable matter. But not only are actually decomposing and putrid substances capable of causing fever—i. e., pyrogenous—but also every kind of pus due to bacterial infection, including the so-called *pus bonum et laudabile*, has the same pyrogenous effect. The micro-organisms (the bacteria) are the most important of the causes of fever, giving rise to it as soon as they, or the dissolved poisonous products of their metabolism (ptomaines, toxines), gain access to the circulation (see § 59). The bacteria act by decomposing their nutritive media, consisting of the animal tissues, the blood, and the lymph, giving rise to fermentative and decomposition processes, and destroying the blood-corpuscles, particularly the white ones, etc. We learned in § 59 that the poisonous products of their metabolism which have been isolated from the bacteria are also capable of exciting a general febrile intoxication. Mention should also be made of the rise of temperature occurring in conjunction with constipation, particularly that following an operation, for instance. This fever is probably due to the absorption of soluble decomposing substances which are formed either with or without the co-operation of bacteria. Every intoxication fever is not by any means to be ascribed to bacteria, as we know that substances capable of exciting fever, such as ferments, can be formed in extravasated blood and in the undecomposed secretion of a wound, without the co-operation of bacteria. We are already familiar with several ferments of this kind which have the power of producing fever, notably the fibrin ferment (Alexander Schmidt), which causes a rise of temperature to take place in the animal into which blood has been transfused, particularly when the blood is taken from an animal of another species. Hammerstein investigated the blood of fifteen patients during fever, and found fibrin ferment existing in a free state

in the blood of twelve. He also found it free in the blood of two patients who did not have fever. The presence of the fibrin ferment in the blood during fever is not constant, consequently no satisfactory theory of fever based upon the fibrin ferment can be established. Solutions of hæmoglobin also have a pyrogenous action—i. e., they are capable of exciting fever. Schmiedeberg has isolated from the blood another ferment, histocym, and has demonstrated that this body, which is a product of the normal metabolism, when introduced into the circulation in sufficient quantities can give rise to high fever. Bergmann and Angerer have shown that other ferments, such as pepsine, pancreatine, etc., have the same power.

This non-bacterial ferment fever, as we may call it, is observed after subcutaneous injuries of bones which are accompanied by considerable extravasation of blood. This is the explanation of a rise in temperature, which may reach 39° to 40° C. (102·2° to 104° F.), and which makes its appearance after a subcutaneous fracture, a severe contusion of a joint, or a subcutaneous injury of soft parts. In the same category belongs, perhaps, the fever following absorption of the undecomposed primary secretion of a wound, called aseptic wound fever, and which may cause the temperature to rise as high as 40° C. (104° F.), even when the repair of the wound runs a perfectly aseptic course (Volkmann and Genzmer). Nevertheless, I believe, at present, that this aseptic wound fever is mainly the result of a too free use of carbolic acid during the operation. If the wound is much irritated, especially by such an antiseptic as carbolic acid, there will follow, not infrequently, extravasations of blood into the wound, there will be a considerable amount of secretion, and the above-mentioned ferments will develop in the stagnant blood, and, even though the wound remains aseptic, these ferments will give rise to the so-called aseptic wound fever. Since I began to use bichloride of mercury instead of carbolic acid, and particularly since I began to make less free use of the poisonous antiseptics, I have no longer observed this aseptic wound fever.

Chronic Ferment Intoxication.—Langenbeck and Cramer have recorded an interesting case of chronic ferment intoxication with continuous high fever, cough, and occasional diarrhœa in a young woman who had a blood cyst the size of a goose-egg on the thigh. The blood cyst had probably developed from a pre-existing cavernous angioma. After its operative removal all disagreeable symptoms immediately vanished. Within the cyst, as in all blood which is not in contact with the normal walls of the vessels, or which becomes stagnant, there had developed different ferments, amongst them Schmidt's fibrin ferment, which had then gained access to the general circulation, as the cyst, from the cavernous structure of its walls, was in direct communication with the vascular system. The febrile symptoms, and

the coagulation processes in the capillaries of the lungs and intestines, were caused in this way, corresponding in every respect to the facts which had been noted by Köhler, Bergmann and others in their experiments on ferment intoxication.

We are able, then, to distinguish two classes of absorption fever, the first being the fever caused by micro-organisms and the poisonous products of their metabolism (ptomaines, toxines) which have gained access to the circulation, and the second being the fever which follows the absorption of the disintegrated products of the body, these products differing but little from the substances formed in the physiological metabolism of the body (non-bacterial ferment fever).

The part played by the nervous system in the production of any one of the various kinds of fevers is briefly spoken of on page 300.

Explanation of the Febrile Process.—How do the factors so far known to be capable of causing fever, the bacteria and the products of their metabolism, the non-bacterial ferments and the central nervous system, how do these factors act? in other words, in what way does the principal symptom of fever, the rise in temperature, come about? It is well known that the body temperature normally regulates itself within moderate fluctuations, and that the amount of heat formed and lost occasionally changes even in health—it increases and diminishes. The amount of heat given off by the body is influenced by the clothing or coverings of the body, by the perspiration, by the circulation of blood in the skin, and, finally, by the increased or diminished excretion of warmth and moisture through the lungs. The amount of heat developed is altered by the voluntary or involuntary increase of muscular activity, by the processes going on in the glands and tissues, by the ingestion of nutritive material, or, in other words, by the increased or diminished supply of fuel. The nervous system, through its reflexes, regulates these various portions of the apparatus, causing each to assume its proper activity, and thus is explained the constancy of the temperature of the body.

During fever the amount of heat produced is, in the first place, increased, and the substances which excite fever must somehow affect those parts of the body which regulate the production of heat. We are ignorant of the exact manner in which this takes place during the febrile process. We can only say that the physiological warmth of the body is the product of the biochemical metabolism of the tissues, and the febrile agent causes an increased metabolism, and consequently an increased production of heat. It can be proved that the metabolism or combustion is actually increased during fever. The increased consumption of oxygen, the increased excretion of carbonic acid and nitrogenous substances, particularly urea, are all evidences of the truth of this. The increase in urea corresponds in general to the severity of the fever, and, according to Cohnheim, no matter how little food is administered, there may be three times more urea excreted than normally, and it may amount to forty to fifty grammes per diem. This increased secretion of urea means that a greater disintegration of albumen is taking place within the

body. Leyden gives the excretion of carbonic acid as one and a half to two and a half times more than in a state of health.

Are there certain tissues in which the increased production of heat is more marked than in others? This question has not as yet been answered. We only know that muscular tissue, particularly that of the heart, nerve tissue, and the glands, are important factors in the generation of heat. Mosso was unable to demonstrate in the cortex of a dog's brain any circumscribed centre regulating the heat of the body, but he conjectured that the regulating power was widely distributed throughout the brain and spinal cord. Aronson, Sachs and Gottlieb affirm that the heat centre for rabbits exists in the corpus striatum.

The blood is certainly one of the most important sources in which a rise of temperature in fever takes place, and this is particularly true in wound fevers, where it contains bacteria and the dissolved poisonous products of their metabolism. By the latter's presence in the circulation we know that the blood becomes altered and that the white blood-corpuscles are destroyed. It is probable that the increased metabolism and the rise of temperature are the results of the alteration in the blood, since the heart and the walls of the vessels are directly affected by the noxious substances, particularly the dissolved poisonous products of bacterial metabolism. Consequently Bergmann has advanced the view, and it seems to me to be the correct one, that the cause of the febrile rise of temperature is to be sought for in an increased metabolism in the blood. The alterations in the blood, according to Bergmann, are the most essential of all the accompaniments of fever. In order to retain the constancy of the composition of the blood, all the machinery in the body designed for this purpose exhibits a more intense activity, and in this way is explained the increased metabolism and rise in temperature which occurs in fever. On account of the elevated temperature of the blood the further development and spread of certain species of pathogenic bacteria are prevented. It is a fact that in anthrax infection, for example, the animal affected has only to be repeatedly cooled off to make the bacilli appear immediately in the blood. The fever or elevation of the temperature of the body and the greater activity of its metabolism is all a conservative process which the body makes use of to more rapidly get rid of the injurious substances which have gained access to it.

In other cases, where there is no intoxication or infection of the blood or tissues, the rise in temperature is due to influences connected with the nervous system, as we have before remarked.

Loss of Heat during Fever.—What are the conditions as regards the amount of heat lost during fever? Ordinarily the amount of heat lost during the chill is less than normal, but during the height of the fever, according to Leyden's measurements, it is greater, being for temperatures above 40° C. (104° F.) double the normal, and even triple when there is an abundant secretion of sweat. Nevertheless the body is unable to get rid of its excess of warmth, because the amount of heat produced is continuously increased during fever, whilst the amount lost fluctuates, at one time being greater than normal, and at another less. The diminution in the amount of heat lost is due to the contraction of the cutaneous blood-vessels, which, as we saw on page 301, begins before the rise in temperature.

Traube, particularly, taught that the cause of fever was to be found in the diminished amount of heat lost, or rather in the pathological changes connected with the loss of heat. It is more correct to ascribe the cause of fever to the increased production of heat resulting from the more active metabolism, in conjunction with a pathological alteration in the amount of heat lost. The amount of heat lost is not constant, as Traube thought, but it is pathologically altered, being at one moment increased and at another decreased. Traube was wrong in denying an increased production of heat in fever.

Definition of the Febrile Process.—If we should wish to formulate a definition of the febrile process, we can say, with Recklinghausen, that fever is a disturbance which increases the metabolism of the materials of the body, especially the tissues which are rich in albuminous substances. This increased metabolism may have its cause in the nervous system or in the blood. Recklinghausen considers that the part of the system principally affected by fever is the motor apparatus of the vascular system, consisting of the heart and muscular coat of the vessels which are regulated by the vasomotor nervous system. The latter plays, according to Recklinghausen, one of the most important parts in the production of fever. The typical symptoms of fever result from a combination of excitation of the nervous and vasomotor apparatus, with an increase in the biochemical processes carried on by the tissues of the body, due to certain causes. The exciting cause of the fever leads to molecular changes in the body substances, but how this comes about still baffles us.

Treatment of Fever.—We shall confine ourselves to the treatment of wound fever. It is mainly surgical, and consists, in the first place, in properly treating the existing injury. The best prophylactic measures in the treatment of wound fever consist in carrying out strictly the rules of antisepsis and asepsis. It is very important to provide for the escape of secretions from the wound by means of careful drainage. If fever makes its appearance in a patient who has been wounded or operated upon, it is advisable to examine the wound carefully to determine whether there is a retention of the secretion or some other abnormity. In wounds which have been sutured, which involve the scalp, for instance, it may be sufficient to remove the sutures and permit a free escape of the retained secretion, and the fever will thus often disappear very promptly. In other cases deep incisions may have to be made on account of the retention of secretions, and abundant drainage may be necessary. I make it a rule to change the dressings on patients who have been injured or operated upon if the temperature rises above 38·5° C. (101·3° F.). If the wound is really aseptic, as in fresh injuries, or after operations, healing without fever is usually assured.

The different wound diseases due to infection must receive their special treatment (see §§ 66–82). If the temperature becomes too much elevated, or if the duration of the fever threatens to cause serious weakness of the patient, in addition to the above briefly outlined local treatment of the wound, it is advisable to adopt other suitable means of treating the fever, just as in ordinary febrile diseases. The best way of reducing the temperature when there is no contraindication consists in the employment of cool baths, cold packs, and sponging off with cold water.

The cold-water treatment of fever is considered by many physicians the best means at our disposal for reducing the temperature. It is used either in the form of baths at a temperature of 20° C. (68° F.), in which the patient is immersed for ten minutes, or baths at a temperature of 24° C. (75·2° F.), which are gradually cooled down during fifteen to twenty minutes to a temperature of 22° C. (71·8° F.). At the same time, in proper cases cold water is poured over the patient, or even ice water, as he lies in the tub. This serves as an excellent stimulant to respiration and the psychical functions. The patient is then brought back to bed without being previously dried off, as in this way the cooling off will continue longer. Wine should be administered freely as a stimulant while the patient is being subjected to this treatment. The reduction of temperature by medicaments, such as quinine, digitalis, veratrum viride, sodium salicylate, antipyrine, etc., should be employed when the patient cannot stand cold baths, or when, for some reason or other, their use is not practicable.

The action of the antifebrile medicaments, such as antipyrine, has been repeatedly tested in recent times, and it has been proved that they act principally through the nervous system, particularly the vasomotor part of it, and the heat centres in the brain; they increase the amount of heat lost, or they diminish the amount of heat produced, or they do both. Maragliano demonstrated that kairine, antipyrine, thalline, quinine, and salicylate of sodium, whether administered during fever or in health, caused dilatation of the cutaneous vessels, and thus increased the amount of heat lost by radiation.

The best treatment by the surgeon of wound fever consists in a careful investigation of the wound, and, as far as possible, in remedying any abnormity which may exist. The treatment of the rise in temperature, if present, is next to be considered, though it will generally not be necessary to do more than to rectify any abnormal condition which may be found in the wound. At present antipyresis—i. e., the reduction of elevated temperatures—is not so energetically carried out as it used to be even in medical cases. Lately we have been giving up

more and more the idea that the temperature curve is the only consideration which determines our treatment of fevers. Repeated observations have demonstrated that there is no truth in the idea that man cannot survive an elevation of the specific heat of his body above 42° C. (107·6° F.). Strümpell and others have declared that the reduction of the increased body temperature should not form the only part of our treatment of fevers. A routine treatment of fever is not a good plan. Every case must be treated symptomatically, according to the conditions which may arise. Too energetic antipyresis—i. e., the adoption of too active measures for reducing temperature—can frequently do more harm than good, from the fact which we mentioned before, viz., that the temperature of the body must be higher than normal to render possible the sudden or gradual destruction of many species of bacteria; and if the temperature of the body is lowered, infection of the blood is favoured.

It is wise to give patients who have fever easily digestible food, and to restrict its amount and variety. Cool, effervescing waters with citric acid, fruit juices, and wines should be allowed as drinks. If an individual has been accustomed to the use of alcohol, the latter should not be denied him entirely, as otherwise nervous complications, or even delirium tremens, may make their appearance (see § 64). Furthermore, it is known that alcohol has the power of directly reducing temperature.

§ 63. **Shock.**—By *shock* is understood a peculiar state of depression of the nervous system, which is apt to be excited reflexly by injuries involving a shaking up or contusion of the sensory nerves.

Etiology of Shock.—Fischer, Goltz, and Seabrook consider the essence of shock to be a paralysis of the vasomotor centre in the medulla oblongata, produced reflexly by a contusion or violent disturbance of the sensory nerves in the manner illustrated by Goltz's well-known experiment on the frog. By repeatedly striking the abdomen of a frog there is produced a peculiar state of collapse, which can terminate fatally by cardiac paralysis, the heart stopping in diastole. The cause of these phenomena lies in the fact that by mechanical irritation of the intestines, or the irritation of any sensory nerves, the activity of the brain and, above all, of the vasomotor centre in the medulla oblongata, becomes reflexly altered, weakened, or paralysed. As a result of this there follows a diminution or paralysis of the vascular tone, particularly in the arteries. There is a weakening in the propelling force driving on the stream of blood, the speed of the current lessens, and the blood pressure diminishes; the blood is unequally distributed, the arterial system is less full, the lungs and brain are anæmic, while, on the other hand, the blood collects in the veins, particularly those in the

abdomen. Eventually the disturbances in the circulation may become so pronounced that the heart's action ceases.

Seabrook attempted to determine the nature of shock by experiments on animals, making contusions of the tissues in both warm- and cold-blooded species, and he reached the same conclusion that has been given above. He determined by his experiments that external violence, acting through the sensory nerve trunks, so affected the medulla, and the vasomotor centre in particular, that after a brief period of irritation a condition of depression followed which resulted in a permanent dilatation of the blood-vessels. The inhibitory nervous system of the heart plays only an unimportant part in shock, except when the terminal branches of the vagus, as in Goltz's beating experiment, are directly acted upon by the violence causing the shock. The paralysis of the vasomotor centre is sufficient for explaining all the symptoms which are manifested by patients in a condition of shock. By the paralysis of the muscular coat of the smaller arteries the blood current loses part of the force by which it is propelled, the blood flows more slowly, and, following the law of gravitation, sinks into the vessels which are most dependent, particularly the large abdominal veins. Thus not only do these become distended with blood, but, in addition, the right heart soon becomes overloaded ; the heart's action is interfered with, the pulse grows weak, frequent, and small. The abnormal distribution of the blood, the anæmia of the skin and the brain, due to the overfilling of the abdominal veins, cause the paleness, the coolness of the superficial portions of the body, and the cerebral symptoms, somnolence, and motor weakness.

Symptoms of Shock.—The sum-total of the symptoms of shock in man correspond exactly to the facts which have been determined experimentally. All the manifestations of shock can be traced back to the paralysis of the vasomotor nerves produced reflexly by the contusion of the sensory nerves.

The *characteristic symptoms of shock* are a marked pallor and coolness of the skin and visible mucous membranes; the face is without expression; the eyes are dull and staring, the pupils are dilated, and react slowly. The heart's action is plainly delayed, irregular, and weak; the pulse is thready or imperceptible; the respiration is irregular and long; deep breaths alternate with shallow inspiratory efforts. The mind is dull and reacts slowly; the patients are completely apathetic, and will only answer questions tardily and unwillingly. The sensibility of the superficial portions of the body is impaired, and the energy of muscular movement is diminished. Not infrequently there is nausea or actual vomiting. The temperature is about 1° to 1½° C. (1·8° to 2·7° F.) below the normal. In other cases, instead of the above-described torpid form of shock, there will be a more active set of symptoms—in other words, the patients are more excited, they fling themselves about, cry out, shriek, and act like maniacs.

It is undoubtedly true that shock occasionally changes gradually into deep syncope and ends in death, particularly in the case of neuropathic, anæmic individuals. In such cases there will usually be found complicated injuries with severe loss of blood, and the post-mortem examinations will frequently show that there are also severe internal injuries, perhaps, of the brain. As a general rule, patients suffering from uncomplicated shock will recover after the lapse of a longer or shorter time, ordinarily after a few hours. Sometimes a psychical change persists for a certain length of time, but eventually perfect recovery will take place. All nervous manifestations, syncope, etc., which follow severe losses of blood and which may look very much like shock, should be carefully distinguished from true shock (see §§ 87–89).

The individual symptoms of shock, particularly cerebral shock, will be described in the Special Surgery under Concussion of the Brain. The latter injury may cause the patient to lose more or less completely all recollection of the accident. He may not be able to remember how he was hurt, he may have no idea of distance and time, and may even forget everything he did, saw, or heard for several days before the time of his injury. As the circulation in the brain becomes in time gradually restored and regulated, the patient may recover some of his lost memories, but a part of his experiences, recollections, and conceptions will remain lost forever.

The Treatment of Shock.—The *treatment* of shock consists, in the main, in overcoming as soon as possible the existing paralysis of the vasomotor nerves, together with the accompanying disturbances which the paralysis gives rise to. To combat effectively the cerebral anæmia, the head of the patient should be placed low down; but if venous congestion of the face becomes marked this position of the head must be immediately given up. Fischer and König are right in recommending vigorous stimulation of the skin by sinapisms, electricity, rubbing the extremities, applying dry heat, etc. In fact, Goltz's beating experiment fails if combined with vigorous irritation of the sensory nerves of the extremities. Internally warm stimulating drinks, strong coffee, hot wine, whiskey, etc., should be administered; there should also be given subcutaneous injections of camphor or calabar extract, digitalin, and atropin. Tincture of digitalis can be tried by mouth instead of subcutaneous injections of digitalin. Dercum has highly recommended the rectal use of a musk emulsion (0·9 to 1·25 gramme), with fifteen drops of the tincture of opium or an enema of strong, black coffee. The respiration must be carefully watched, and, if necessary, kept up artificially, as described in § 13. One must avoid under-

taking an operation with chloroform narcosis upon a patient in a state of shock. The chloroform narcosis may alone be sufficient to cause the weakly contracting heart to come to a complete standstill. Patients who are suffering from shock should, as a rule, not be operated upon; but if it is absolutely necessary to adopt some operative measures, such as checking hæmorrhage or the like, the operation should be done without chloroform.

§ 64. **Delirium Tremens.**—By *delirium tremens* (drunkard's delirium) is understood an acute outbreak of chronic alcoholic poisoning, which is particularly liable to occur when a habitual drinker is compelled, by some injury or acute internal disease, to remain for some time in bed. Delirium tremens, owing to the increase in the misuse of alcohol, has been observed in youthful subjects, and even in five- to eight-year-old children. These children, whose parents had, as a rule, been addicted to drink, had for a long time been taking daily increasing amounts of alcohol. The delirium usually breaks out very soon after the injury or operation. According to Krugenberg, in about fifty per cent. of the cases there exists, besides the alcohol habit, a tendency to some nervous disease such as epilepsy. Krugenberg, basing his opinion on three hundred and one cases of alcoholism which he observed, amongst which there were one hundred and sixty-one cases of delirium tremens, denies that the sudden stoppage of alcohol plays a causative part in the production of delirium tremens.

The first *symptoms* manifested are loss of sleep, great restlessness, and constant talking. The trembling movements are characteristic, and particularly evident when the patient is told to hold out his arm or to show his tongue. The patients see animals of every description, and they are very apt to complain that their rest is disturbed by mice, rats, etc., crawling about them. The delirium is generally connected with marked hallucinations, and not infrequently there is pronounced maniacal excitement. They try to get up, and they may even walk about without pain though they have a fracture of the leg. They make frequent attempts to run away, and consequently must be carefully watched. Very often they will have to be put in a strait-jacket and tied in bed. The prognosis of the delirium is in general favourable, though it frequently happens that old people, in particular, die rather suddenly with symptoms of collapse. It must also be borne in mind that the original injury from which such a patient may be suffering—a subcutaneous fracture, for example—may easily run an unfavourable (complicated) course if his violent movements are not carefully enough guarded against, and he is not properly treated. The post-mortem examination will usually reveal the ordinary changes which occur in the

organs of drunkards, particularly chronic gastritis, atheromatous degeneration of the arteries, fatty liver, the kidneys of Bright's disease, thickening of the cerebral membranes, etc.

Treatment of Delirium Tremens.—The treatment of delirium tremens consists, in the first place, of vigorous prophylactic measures. It is exceedingly important that the daily amount of alcohol which the patient has been accustomed to should not be stopped, and even more alcohol should be given during his illness than he is accustomed to take normally. In this way an outbreak of delirium tremens can often be avoided. Considerable amounts of alcohol should be administered, best in the form of strong wine or cognac—about one half to three quarters to one litre in twenty-four hours; and, in addition, the patient should be given an easily digestible diet—meat, bouillon with eggs, etc. Furthermore, it is a good plan to administer opium in large doses (0·10 to 0·40 gramme every two hours), with or without combining it with Rochelle salts, or opium with chloral hydrate, or morphine subcutaneously, to combat the restlessness and loss of sleep from which the patient suffers. I do not, as a general thing, like these narcotics in the treatment of delirium tremens, and prefer large doses of alcohol, which will often bring on, without the assistance of narcotics, the sleep which is the precursor of a speedy convalescence. I employ opium or morphine only in bad cases of great restlessness or mania. When the latter condition is present, it is an excellent plan to use cold douches, continued for a considerable length of time, until the patient is put to bed in an exhausted condition.

Sawadskje praises the action of strychnine, which he exhibits in doses of 0·003 gramme for a week, to counteract the desire for drink, and as a treatment of the delirium tremens and the conditions which it gives rise to.

§ 65. **Delirium Nervosum and Psychical Disturbances which may follow Injuries and Operations.**—By delirium nervosum is understood a condition of nervous excitement without fever (Billroth), which is sometimes observed in hysterical persons, following injuries and operations. The delirium may be of the wild, maniacal type, or it may be melancholic. Some cases have the character of hysteria, or dementia senilis. The delirium of sepsis, alcoholism, and poisoning from iodoform, morphine, chloroform, and of uræmic states, etc., of course do not belong to this class. Le Dentu has noted over twelve cases of delirium nervosum following operations, and he has collected sixty-eight cases from the literature on the subject, thirty-eight of which were observed after operations on the female genitalia. Delirium nervosum generally makes its appearance two to five days after the opera-

tion, and lasts several days or a week, and in exceptional cases may terminate in death (Le Dentu). In the majority of instances the psychical disturbances occurring in connection with operations upon the male and female sexual organs, or following operations upon the face, etc., are of a transient nature. Mention should also be made of the delirium of collapse, which is occasionally observed after a sudden fall of a high temperature—for instance, after the defervescence in erysipelas, and in hysterical individuals with a subnormal temperature. This delirium of collapse is usually accompanied by transient psychical disturbances. The prognosis of collapse delirium is generally favourable, and the acute mental aberration often disappears in a few days, or even in a few hours.

§ 66. **The Infectious-Wound Diseases.**—The existence of infectious diseases of wounds has been established beyond a question by the labours of Pasteur, Billroth, Klebs, Eberth, and, above all, by Koch and his followers. Thanks to their careful researches, we now know that the infectious diseases of wounds are caused by micro-organisms, or by the products of their metabolism (ptomaines, toxines). (See § 59.)

Koch, experimenting upon animals, excited infectious-wound diseases which possessed many similarities to corresponding diseases in man. However, the facts which are experimentally ascertained as regards animals cannot be directly applied to man, as we know that different species of animals are affected differently by the same poisons. A poison or a certain species of bacteria may not be injurious for one kind of animal, while this same poison may immediately excite dangerous symptoms in another. Furthermore, totally different classes of micro-organisms may produce in different animals diseases which are very similar. The bacillus of mouse sepsis is totally different from the bacillus which causes sepsis in rabbits, and it does not cause sepsis in the latter. The sepsis which occurs in mice from infection by a bacillus has only been observed in house-mice, while field-mice are immune from its effects, etc.

Koch was the first to develop an exact method for investigating the infectious diseases of wounds. He introduced improved methods of illuminating and staining preparations, and thus made it possible for us to study the shape, distribution, and number of the bacteria in the body. He, moreover, made cultures of the bacteria which he had found upon solid nutritive media, so as to observe the characteristics of their growth and the immutability of their species. These pure cultures were then reinoculated upon animals, for the purpose of exciting the same disease which they had first caused. We have these exact methods of his to thank for our knowledge of the etiology of the

infectious diseases of wounds, and the facts ascertained by experiments upon animals conform very closely to what we have observed in man.

Every inflammatory or suppurative process which occurs in the wound, such as circumscribed and diffuse cellulitis, acute inflammations of the lymph and blood-vessels (lymphangitis, phlebitis, arteritis), erysipelas, hospital gangrene (wound diphtheria), pyæmia, septicæmia, and tetanus, are all included amongst the secondary infectious diseases of wounds which may make their appearance in man. These infectious-wound diseases are all caused by bacteria. This class of diseases also includes anthrax, hydrophobia, glanders, etc., which are diseases communicated from animals to man. Actinomycosis, tuberculosis, and syphilis are also due to infection by micro-organisms, and there are still other diseases of a like character which we shall learn about later. The bacteria are capable of gaining access to the tissues or the fluids of the body through any wound, even the smallest interruption in the continuity of the skin or mucous membranes. The trauma in itself plays no part in the origin of the infectious-wound disease, and the gravest injuries, the most extensive operations, will run their course without inflammation and without suppuration, provided only the bacteria are kept out of the wound. The best way of *preventing* an infectious-wound disease is to employ the most careful asepsis or antisepsis in every operation or injury and in the application of every dressing. The possibilities of surgery since the introduction of antiseptic and aseptic methods have increased to a most wonderful degree, and our responsibility towards our patients has become correspondingly greater. Every physician should constantly bear in mind that he may cause the death of his patient by a single transgression of the rules of asepsis—by an unsterilised and non-aseptic instrument, or by an unclean finger.

The infectious diseases of wounds have, corresponding to the action of the bacteria, partly a local and partly a general systemic character. As was stated in § 62, the general disturbances, the fever, and the general poisoning are caused by the absorption of the metabolic products of the fungi, which, as we shall see when we come to septicæmia, can give rise to systemic poisoning even after they have become separated from the fungi. Their metabolic products thus give rise to an intoxication which, like every kind of poisoning by chemical substances, cannot be transmitted by inoculation. Infectious diseases caused by the bacteria themselves are, on the contrary, capable of being transmitted from one individual to another. We shall see that each one of the infectious-wound diseases to which man is subject is excited by a specific micro-organism. There are cases, however, which are not due to in-

fection by any single species of bacteria, but are mixed infections—in other words, they are caused by several different species acting together. The questions concerning the significance of the micro-organisms in the causation of the infectious-wound diseases and the various methods for investigating them have been described in § 59.

In all febrile infectious diseases of bacterial origin the cause of the fever is to be ascribed to the changes in the blood brought about by the bacteria, or rather the products of their metabolism. Furthermore, in the fevers due to unformed ferments, or non-bacterial solutions, such as fibrin ferment, pepsin, trypsin, or hæmaglobin, it is principally, as described in § 62, the change in the composition of the blood which gives rise to the increased oxidation processes going on in the blood, and to the rise of temperature.

§ 67. **Inflammation and Suppuration of a Wound—Etiology.**—Though it was once believed that all suppuration was caused by micro-organisms, we learned on page 240 that Grawitz, De Barry and others have demonstrated that suppuration can also be excited without bacteria in dogs and rabbits by aseptic (germ-free) chemical substances, such as turpentine, nitrate of silver, mercury, etc.

Moreover, sterilised cultures of various micro-organisms, or the sterilised products of their metabolism (cadaverine, putrescine, pentamethylendiamine), have a similar (pyogenic) power of exciting suppuration. When Behring added iodoform to the cadaverine the latter never produced suppuration.

Though it is undoubtedly true that suppuration can be excited by a whole series of germ-free chemical substances, it is just as certain that suppuration is produced in man, under ordinary conditions, by the presence and life of certain distinct micro-organisms, no matter whether the suppuration takes the form of a simple felon, a furuncle, or a dangerous phlegmon. The question does not involve two opposing principles, since the bacteria themselves give rise to suppuration mainly through the chemical products of their metabolism. Ogston, Rosenbach and others have studied the micro-organisms which are present in acute suppuration, and they have frequently found only a single species, but at other times several. Suppuration in man is mainly due to cocci, which are found either in irregular masses arranged in groups (the staphylococcus, Fig. 254), or in the form of chains (the streptococcus, Fig. 256). The streptococcus is more apt to give rise to spreading erysipelatous inflammations, the staphylococcus to localised inflammation and suppuration, and the latter is the true pus coccus. The lodgment of pus cocci, or rather the starting up of suppuration, is favoured by local lesions as well as by weakness of the whole organism.

Different Kinds of Pus Microbes.—Ogston, Rosenbach and Passet have made pure cultures of the various bacteria found in acute suppuration upon solid nutritive media (peptone-gelatine-meat extract, meat-peptone-agar, hardened blood serum, potatoes). Rosenbach has cultivated five different species of microbes which he obtained from thirty acute abscesses, leaving out the abscesses which contained decomposing matter and were filled with bacilli, spirilla, and various kinds of cocci in addition to the pus cocci. Amongst these five kinds of microbes Rosenbach found one species only once, an oval coccus (bacterium). The others were the staphylococcus pyogenes aureus, the staphylococcus pyogenes albus, the micrococcus pyogenes tenuis (rare), and the streptococcus pyogenes. Passet cultivated eight different kinds of pus microbes—the staphylococcus aureus, albus, and citreus; the streptococcus pyogenes, a micro-organism resembling the pneumococcus; the bacillus pyogenes fœtidus (Fig. 259); the staphylococcus cereus, and flavus. They are all capable of exciting acute suppuration. The cultures of the chain cocci of pus cannot be distinguished from the cocci of erysipelas (see § 71). From Passet's experiments it appears that the effect upon animals of the pus streptococci is almost exactly the same as the effect produced by the cocci of erysipelas. All the microbes found in foci of suppuration, when transplanted into milk will cause the latter to coagulate. The fact that pyogenic microbes may in one instance cause only trifling suppuration, in another a dangerous diffuse phlegmon, which may threaten life, and in still another an acute inflammation of the bone marrow (osteomyelitis), or pyæmia with its metastases, is explainable partly by the differences in the points of invasion and partly by the variability in the numbers and virulence of the micro-organisms which gain access to the system. While suppuration is going on, pus cocci can frequently be demonstrated in the blood, urine, and sweat (Brunner, Tizzoni, etc.).

Artificially obtained Immunity from the Poison of Pus Cocci.—In exceptional cases the pus of acute suppuration does not contain any microbes, though this does not necessarily mean that none have been present at an earlier period, since we know from Rosenbach's experiments that there are bacilli which cause suppuration and then perish very soon afterwards.

Lindwurm and Pazet, sixty years ago, recorded a temporary immunity from poisoning by pus cocci in animals, brought about by the injection of pus. P. Reichel has obtained temporary immunity in dogs from the virus of pus cocci by injecting into their peritoneal cavities pure cultures of the staphylococcus pyogenes aureus or by inoculating them with the germ-free infiltrate, or products of the metabolism of the staphylococcus pyogenes aureus. This immunity was of very brief duration, lasting only a few weeks.

Effects of Bichloride upon Pus Cocci.—According to Abbot, bichloride of mercury is capable of rendering harmless only a certain number of pus cocci (staphylococcus pyogenes aureus)—sometimes more and sometimes less—depending upon the virulence, or rather the resisting powers, of the cocci.

The Most Important Pus Microbes.—1. The staphylococcus pyogenes aureus (Figs. 254, 255), so designated because of its golden or orange-yellow colouring matter, is the species of micrococcus which is most frequently found in suppuration. (According to Fränkel, it is found in eighty per cent. of all the cases examined). These cocci are incapable of motion, vary in size,

and are arranged in clusters, often in the form of diplococci. It is present in pus, in the air, in dish-water, and in the earth. The staphylococcus pyogenes aureus can be grown in pure cultures upon gelatine, agar-agar, potatoes, and blood-serum. In gelatine plate cultures, at the end of the second day, small punctiform colonies appear, having a yellow colour and a sharp, slightly depressed border, separating them from the non-fluid gelatine. Puncture cultures in gelatine at first reveal a dim, greyish point, which after about three days becomes yellowish, and then orange-coloured; then the gelatine becomes liquefied, and the culture sinks to the bottom. Linear cultures upon agar-agar (Fig. 255) give an opaque yellow culture which has a crooked outline. Upon potatoes there first forms a thin, whitish layer, which gradually becomes orange-yellow, and smells like paste. The staphylococcus pyogenes aureus grows in blood serum in the same way as upon agar-agar. All cultures develop pretty rapidly—most so at temperatures between 30° and 37° C. (98·6° F.), and more slowly at ordinary room temperatures. They have not hitherto been seen to form spores. This coccus possesses great powers of retaining its vitality, and is exceedingly resistant, for instance, to drying, chemical substances, and boiling water. To the latter it has to be subjected for several minutes before it is killed. The staphylococcus pyogenes aureus can exist a great while without atmospheric air, is facultative aërobic, and gives rise to the formation of no gas or stinking decomposition; it peptonises albumen and liquefies gelatine. Gram's method is excellent for staining the staphylococcus pyogenes aureus.

Fig. 254.—Pus with staphylococcus (Flügge). ×800.

The pathogenic effect of the staphylococcus pyogenes aureus, when used experimentally upon animals, varies with the manner in which it is employed. Inoculations have been made upon man by various experimenters. Garré inoculated himself by inserting a pure culture in a small wound at the root of his finger-nail, and obtained an extensive suppuration; by rubbing a great number of the cocci upon the healthy, unbroken skin of his forearm he produced a large carbuncle. Subcutaneous inoculations in mice, guinea-pigs and rabbits are without any result, though subcutaneous injections in the two latter classes of animals give rise to the formation of abscesses. Injections made into the peritoneal cavity cause a violent suppurative inflammation, which usually kills the animal in a few days. Injections of the cocci into the blood-vessels give rise to inflammations of joints and to diseases of the kidneys, and metastatic abscesses develop in the muscles of the heart and in the kidneys. If the valves of the heart are first wounded, a typical endocarditis ulcerosa results. If, before injecting the cocci into a blood-vessel, a subcutaneous fracture or crush of one of the long hollow bones is artificially produced, the point at which the injury is situated becomes "predisposed" to suppurative inflammation of the medullary portion and periosteum. The staphylococcus pyogenes aureus is the most frequent excitant of acute osteomyelitis (see § 104). Frequently the staphylococcus pyogenes aureus is

found combined with other micro-organisms in cases of suppuration. Artificially acquired immunity from the poison of the staphylococcus pyogenes aureus is described on page 321.

2. The staphylococcus pyogenes albus is in all respects similar to the staphylococcus pyogenes aureus, except in not having the latter's yellow colouring matter. It also appears to be somewhat less harmful, and is of less frequent occurrence than the aureus.

3. The staphylococcus pyogenes citreus was discovered by Passet, and is seldom found in suppurative processes in man. The staphylococcus pyogenes citreus is distinguished by its beautiful lemon-yellow pigment (Fig. 232), but is otherwise exactly like the aureus and albus, except that it takes longer to liquefy gelatine.

Streptococcus Pyogenes.—4. The streptococcus pyogenes (Fig. 256) plays a very important part in the causation of suppuration. It is frequently found alone in abscesses, rarely in combination with the staphylococci. This coccus causes, for the most part, progressive suppuration, and from recent discoveries is thought to be identical with Fehleisen's streptococcus of erysipelas. In the latter disease the streptococcus is found principally in the lymph channels of the skin. The streptococci form chains generally consisting of six to ten to twenty cocci arranged in a row like links, though there may be hundreds of these cocci, or links, in a single chain. The chains are often made up of two parts, or they may be twisted together in thick masses, or arranged in slender bundles. The following are the principal facts as regards the development of pure cultures : Gelatine plate cultures take the form of fine, round, granular dots. Linear cultures upon gelatine plates are thickest at the centre of the line, of a faint brown colour, with the edges of the line plainly punctate, and later becoming graded off in terraces. Puncture, or stab cultures, in gelatine, have a delicate areola at the point where the puncture enters the gelatine, the line of puncture itself being finely granular (Fig. 257). The streptococcus does not multiply upon potatoes, though some individual cocci increase in size, and, when examined by the microscope, chains are seen made up of some large and some small cocci or links. The streptococcus pyogenes grows best at a temperature of 35° to 37° C. (98·6° F.), ordinary room temperatures being less favourable to them. The cultures grow slowly, linear cultures requiring two to three weeks to spread a couple of millimetres. After the lapse of four months the cultures will be found, for the most part, to have perished. Gelatine is not liquefied ; it decomposes albumen in a vacuum; it is facultative aërobic, and is not particularly affected by the absence of oxygen. It is best stained by Gram's method. The streptococcus pyogenes can be found almost anywhere, and its pathogenic effects may be manifested in various ways, accord-

Fig. 255.—Linear culture in agar-agar—Staphylococcus pyrogenes aureus.

ing to the manner and the region in which it gains access to the body. It is found in saliva, nasal and vaginal mucus, and in the urethra of man in health. It is often found in tissues which have undergone morbid changes —for example, in typhoid fever, pneumonia, tuberculosis, pleurisy, and scarlet fever, and under such conditions it may give rise to severe inflammatory complications. Upon the valves of the heart it excites typical endocarditis. When growing in the lymph channels of the skin and mucous membranes it causes cutaneous erysipelas and destructive inflammation of the mucous membranes, and when lodged in the subcutaneous tissue it gives rise to cellulitis, etc.

FIG. 256.—*a*, Streptococcus, × 950; *b*, pus with streptococcus.

Bacillus Pyocyaneus.—5. The bacillus pyocyaneus *a*, Gessard, or the bacillus of green or blue pus, is a small slender rod (Fig. 258) sometimes found in a non-suppurating, serous wound secretion and in ordinary sweat. This bacillus gives to pus or dressings a blue or green colour without causing complications to arise in the reparative process in the wound, and is similar to the bacillus of blue milk. Though somewhat narrower, it is capable of active motion, and frequently takes the form of a string with four to six joints, and less often forms long filaments. It has not been observed to undergo spore formation. When cultivated on gelatine plates, small white points or dots make their appearance within the gelatine, gradually rising to the surface, upon which they spread out. The nutritive medium very soon takes on a greenish, fluorescent colour all around the culture, and after the lapse of about five days the gelatine becomes completely liquefied. In a test tube the bacillus develops almost exclusively in the deeper parts of a stab culture. The gelatine becomes rapidly liquefied, and assumes a beautiful green colour. Upon agar-agar there forms a moist, rather thick yellow covering, which colours the nutritive medium green. Upon potatoes there is developed a dirty yellowish-green scum, with a green discolouration of the adjoining parts. The colouring matter (pyocyanine) is for the most part seen at the free borders of the clusters, and, according to Ledderhose, is an aromatic crystalline compound having no pathogenic properties. According to C. Fränkel, the colouring matter is white when first formed from the bacteria, only assuming its peculiar tinge when brought in contact with the oxygen of the air. The bacilli themselves, and the products of their metabolism, are undoubtedly injurious to animals. If about one cubic centimetre of a fresh bouillon culture is injected into the

FIG. 257.—Star or puncture culture of streptococcus pyogenes.

subcutaneous tissue of a guinea-pig or rabbit there will result a rapidly spreading œdema and suppurative inflammation, causing the death of the animal in a short time. The bacilli will be found at the point of inoculation in the blood and internal organs. Bouchard and Charrin have demonstrated the very interesting fact that it is possible, with the aid of the bacillus pyocyaneus, to check an advancing anthrax infection and to cause it entirely to disappear.

Fig. 258.—Bacilli of greenish-blue pus. × 700.

Bacillus Pyocyaneus β Ernst.—Ernst has described a variety of the bacillus pyocyaneus as the β bacillus pyocyaneus. It forms a blue colouring matter, or rather blue pus, while the other (*a*) bacillus forms the green pigment. Ledderhose has designated the *a* bacillus the bacillus pyofluorescens, and β bacillus the bacillus pyocyaneus β. Generally the two kinds of bacilli occur together and produce a mixed colour.

Other Colouring Matters Produced by Bacillus Pyocyaneus.—Schimmelbusch states that the bacillus pyocyaneus forms, in addition to the green or blue colouring matter, brown and a whole series of colouring matters ranging all the way from brown to green. The production of the colouring depends upon the presence of sufficient air, proper nutritive media, and upon the structure of the bacilli. The latter may assume different forms in different nutritive media, and may even be unable to lose their property of producing colouring matters under natural or artificial conditions.

Fig. 259.—Bacillus pyogenes fœtidus (Passet). × 700.

Red Pus.—There is occasionally observed a red cinnabar-coloured pus. Ferchmin found that the causation of this red pus was to be ascribed to a special form of bacillus with evenly rounded ends, which could be cultivated best at a temperature of 36° to 37° C. in various nutritive media—agar-agar, gelatine, blood serum, potatoes. The red colouring matter is easily soluble in alcohol, and is insoluble in water, ether, and chloroform. In man, the red colour of the pus has nothing to do with the reparative process in a wound. In rabbits especially the bacillus has pathogenic properties.

Other Pus Microbes.—Amongst the other pus microbes mention should be made of the micrococcus pyogenes tenuis, the bacillus pyogenes fœtidus Passet (Fig. 259), and the staphylococcus cereus, albus, and flavus. These bacteria are of subordinate importance as regards man. Recently the bacillus pyogenes fœtidus has been carefully studied by Burci. He proved that it possessed not only pyogenic but even septic properties for rabbits and mice. Neumann and Haegler maintain that the micrococcus pyogenes tenuis is identical with the pneumococcus of Fränkel and Weichselbaum.

Pneumococci and Typhoid Bacilli as Excitants of Suppuration.—There are still other micro-organisms which excite suppuration. It is occasionally produced by pneumococci (Schwartz, Malgaigne) in the form of secondary suppuration in joints during pneumonia, and similar phenomena, due to the typhoid bacillus, may occur during typhoid fever, etc. The suppurative processes occurring in the course of the acute infectious diseases—for example, in diphtheria—are due to the presence of pus cocci. The micrococcus which

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causes suppurative inflammation of the urethra, the vagina, etc.—in other words, the gonococcus Neisser—is discussed in the Special Surgery.

Chronic abscesses, apart from those due to syphilis, glanders, and actinomycosis, are for the most part tubercular, and are caused by a characteristic bacillus (Koch).

Clinical Forms of Inflammation and Suppuration as we meet them in Surgery.—Clinically, inflammation and suppuration may exist in various forms, either as an ordinary superficial suppuration limited to the wound, or the inflammation may extend to the parts in the neighbourhood of the injury and result in a cellulitis. This inflammation may lead to more or less circumscribed suppuration and abscess, or to diffuse and often rapidly spreading inflammatory and suppurative processes. The worst form of spreading inflammation and suppuration is the diffuse, foul-smelling inflammation of the cellular tissue, to which is given the name of septic phlegmon. Inflammation of the lymph vessels is called lymphangitis. Inflammations of the vessels, especially the veins (phlebitis), are very important, particularly as regards their dangerous sequelæ, due to the so-called emboli. The spreading inflammation which involves the skin and subcutaneous cellular tissue, the so-called erysipelas, is caused by an inflammation of the smaller lymph channels, due to the streptococcus pyogenes. The gangrenous breaking down of a granulating wound is called hospital gangrene, or wound diphtheria. Accompanying the inflammation and suppuration caused by micro-organisms, there is more or less fever, due to secondary infection or poisoning of the lymph and blood by the bacteria and the products of their metabolism. This may finally terminate in a fatal general systemic poisoning, which we shall learn about more particularly under the heading of Pyæmia and Septicæmia.

We shall first discuss acute inflammation of the lymph vessels (lymphangitis) and lymph glands (lymphadenitis).

§ 68. **Lymphangitis, Lymphadenitis.** *Acute Inflammation of the Lymph Vessels—Lymphangitis.*—Acute lymphangitis is characterised partly by a change in the lymph and walls of the lymph vessels, and partly by a perilymphangitis—i. e., an inflammation of the connective tissue surrounding the lymph vessels. The starting-point of a lymphangitis is usually some focus of infection; in other words, it is particularly apt to originate from an infected wound. The interruption of continuity in the skin is frequently most insignificant. The inflammatory irritant, the bacteria—and these are generally pus cocci—are taken up by the lymph vessels, and then they spread into the larger lymph channels, and wherever the bacteria become lodged they give rise to inflammation or thrombosis. As a result of the inflammation,

the walls of the lymph vessels undergo a change, the endothelium may perish, and the entire wall may necrose, suppurate, etc. The lymphangitis may terminate in either a *restitutio ad integrum*, with absorption of the exudate and regeneration of the destroyed endothelium, or in abscess formation and necrosis of the walls of the lymph vessels and surrounding parts. Chronic inflammation of the lymph vessels leads to hyperplasia of the connective tissue, with induration of the lymph vessels and the tissue surrounding them.

Histological and Experimental Investigations upon the Movement of the Lymph during Inflammation.—The lymphatic system plays both a passive and an active part in inflammation. As long as the lymphatic vessels remain free from the inflammatory process, they carry off the products of the inflammation, the emigrated leucocytes, and red blood-corpuscles, and the inflammatory process may resolve without going on to the formation of an abscess. An abscess is particularly apt to develop when the walls of the blood- and lymph-vessels become affected to a marked degree by the inflammatory agent, causing a retardation of the lymph current and insufficient removal of the inflammatory products. The slowing of the lymph current may eventually become a complete stasis, with emigration of the leucocytes from the lymph channels and a corresponding infiltration of the tissues, resulting in abscess or gangrene of the affected parts. The changes which occur in lymph-vessels during inflammation are the same as those that occur in the blood-vessels.

Clinical Course of Acute Lymphangitis and Lymphadenitis.—Acute lymphangitis presents the following clinical picture: After the reception of a wound which is not treated aseptically, possibly a superficial abrasion of the skin on the fingers, the patient complains of pain in his entire arm, particularly when it is moved. When the patient is carefully examined there will usually be found a painful swelling of the epitrochlear and axillary glands, and from the still visible wound, or from the site where it existed, there will be seen red stripes leading up to the axilla. There will ordinarily be fever at the same time. The subsequent course of the disease varies. There either occurs, when proper treatment is adopted (rest, elevated position, ice), a complete *restitutio ad integrum*, or there is a continuation of the fever, with an increase of the local inflammatory symptoms leading to suppuration, generally in the form of circumscribed abscesses in the lymphatic glands of the axilla and its neighbourhood. If the inflammation involves the more deeply lying lymph channels, there will be none of the above-mentioned red stripes in the skin. Acute inflammation may then suddenly develop in the corresponding lymphatic glands, which may either entirely resolve or go on to the formation of an abscess. Any lymphangitis is capable of giving rise to extensive inflammation

and suppuration, to cellulitis, erysipelas, suppurative periostitis, generally accompanied by superficial necrosis of the neighbouring bone; also to general systemic infection, pyæmia, or septicæmia, terminating in death. All these possibilities depend upon the nature of the poison which is absorbed, or upon the virulence of the bacteria. Occasionally a severe phlegmon (§ 70), or a general systemic poisoning—particularly pyæmia—makes its appearance at a rather late period, long after the lymphangitis has entirely disappeared. In such cases the bacteria, which were first admitted through an interruption of the continuity of the skin, lie dormant in a lymph gland, and after the lapse of a certain length of time, either spontaneously or as the result of some cause which gives rise to inflammation (a blow, violent muscular movements, etc.), they may suddenly excite dangerous suppuration, and even cause death from pyæmia or general septic poisoning of the whole system. The study of the clinical course of lymphangitis, caused by bacterial infection, teaches us very plainly the necessity of treating with antiseptic principles even the most insignificant wound on the surface of the body.

The Treatment of Acute Lymphangitis and Lymphadenitis.—The treatment of acute lymphangitis and lymphadenitis in fresh cases consists in placing the affected portion of the body in a proper (elevated) position and giving it complete rest. For lymphangitis of the hand the arm should be fixed in the vertical position, upon Volkmann's suspension splint, for instance, which is very serviceable for this purpose (Fig. 177, page 207); the circulation is thus regulated, the afferent arterial current is checked, while the efferent current in the veins and lymphatics is made to flow off more readily, and the inflammatory swelling goes down, usually very rapidly. Ice should be applied in combination with the elevated position, or, if cold is not well borne, moist applications covered over with rubber tissue are excellent. In addition, grey mercurial ointment, very gently rubbed in, serves a useful purpose. The course of the disease must be carefully watched for the appearance of any localised redness and swelling indicating suppuration. Whenever suppuration can be demonstrated by fluctuation, the pus should be let out by incision at the earliest possible moment. Occasionally there will be noticed a great tendency to recurrence, especially after infection by cadaver poisoning (§ 76), and this recurring lymphangitis requires the most careful treatment. In such cases the warm baths recommended by Billroth and others are exceedingly useful. But search should always be carefully made for the possible presence of some focus of infection—some small wound, ulcer, pustule, etc.—and this, when found, should be treated upon antiseptic principles.

§ 69. **Arteritis and Phlebitis.** *Inflammation of the Walls of the Blood-vessels* (*Arteritis*, *Periarteritis*, *Phlebitis*, *Periphlebitis*).—We referred to inflammation of the walls of the vessels in the chapters on inflammation (§ 56) and the repair of wounds (§ 61). We saw that in every inflammation there occurred an alteration in the walls of the vessels, and that in every injury to a vessel and in the organisation of the thrombus an inflammation took place for the purpose of forming a cicatrix in the vessel. Every reparative process which takes place in a wound, even though aseptic in its nature, is an inflammatory change; but the aseptic repair of the injured vessels in a wound and the organisation of the thrombi into vascular connective tissue take place without any disturbance. When an injury, however, becomes infected by bacteria, the inflammation which then develops in the walls of the vessels becomes a matter of great importance.

We shall concern ourselves here principally with the inflammation of the walls of the vessels which results in suppuration—acute suppurative arteritis and phlebitis. Both of these inflammatory processes are very apt to be observed in conjunction with a suppurating wound or ulcer, and are caused by micro-organisms, particularly those micrococci which excite suppuration (staphylococcus, streptococcus, etc.).

The suppurative necrotic arteritis may be secondary to already existing disease of the surrounding tissues. In such cases the inflammation first attacks the adventitia, and then extends to the inner coats of the artery. If the artery contains a thrombus, as is the case after ligation, the thrombus may, from the influence of the bacteria which have entered it, undergo a suppurative breaking down (thrombo-arteritis purulenta), and as a result of the sloughing of the arterial wall a hemorrhage may result which can endanger the life of the patient. In other cases the suppurative thrombo-arteritis is developed by emboli, which carry the infectious material from some focus of infection into the blood-vessels, and, finding lodgment at some point, produce there suppurative changes (metastatic abscesses).

In suppurative inflammation of the veins (phlebitis) practically the same phenomena are observed. It is caused either by the direct entrance of bacteria into the blood-vessels or by the extension to the latter of an infectious inflammation in the surrounding parts; for instance, an acute suppurative inflammation of the cellular tissue may extend and involve the walls of a vein. The inflammation in the wall of a vein, particularly the alteration which it produces in the intima, the endothelium, gives rise to the formation of a thrombus and thrombophlebitis; or else this order is reversed, and the thrombus forms before there is an inflammation of the walls of the vein. In the veins thrombi

are particularly liable to develop in the region of the valves (Fig. 260), as the blood current flows more slowly at these points than at others, and the micro-organisms can thus more easily find lodgment (Fig. 260). If in a suppurative thrombophlebitis the suppurating masses containing micrococci are swept off in the blood current to other parts of the body, wherever they are deposited they form the above-mentioned metastatic abscesses resulting in pyæmia (§ 75). Buday maintains that the lodgment of emboli made up of large particles of tissue or masses of cocci is by no means necessary for the production of metastatic suppuration; the micro-organisms circulating in the blood may become lodged in the endothelium of the vessels, and, growing very rapidly, break through their walls and give rise to phlebitis, thrombosis, and secondary phlegmonous processes. From what has just been said, it follows that every infection of the blood by micro-organisms, every suppurative inflammation, as soon as it extends to the walls of a vessel and reaches its lumen, is an exceedingly grave event on account of the spreading of the pus, or rather the bacteria, through the circulation.

Fig. 260.—Thrombus in the valve of a vein (schematic).

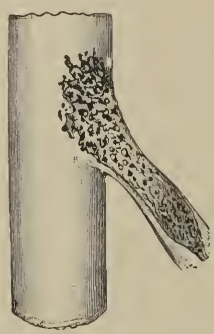

Fig. 261.—Purulent thrombus of a vein (schematic).

Other inflammatory conditions, affecting the walls of the vessels, which concern the surgeon, are the acute inflammations which are particularly liable to occur in the intima of the aorta and the other arteries in pyæmic and septic infections of the general system, and which are due to the bacteria or the products of their metabolism circulating in the blood. Anatomically, these inflammations are characterised by the formation of groups of small cells in the intima and the other coats of the arteries, and by a fibrinous exudation into the intima, the latter being sometimes covered by a tough layer of fibrin.

It is important for the surgeon to bear in mind that the acute inflammations occurring in the walls of the vessels in conjunction with injuries to the soft parts are, after all, only partial manifestations of other local and general bacterial infections, such as a circumscribed or spreading cellulitis, erysipelas, pyæmia, or septicæmia. We shall therefore abstain from going into the diagnosis and treatment of inflammation of the walls of the vessels separately at present, as this

subject will be brought up again in connection with the diagnosis and treatment of the inflammations or infections of the surrounding parts.

The phlebitis and the periphlebitis which sometimes occur in a more or less isolated form like a lymphangitis, and often originate from some insignificant injury, are diagnosed and treated briefly as follows: The subcutaneous veins feel like cords on account of the inflammatory thickening of their walls and the thrombosis which takes place in their interior. The process is essentially a periphlebitis with inflammatory infiltration of the sheaths of the vessels, and the veins are not always thrombosed. If, however, thrombi do exist in the veins, there is usually a corresponding œdematous swelling from the disturbance in the circulation. The treatment, particularly when the disease occurs in the lower extremity—and it sometimes occurs spontaneously in individuals with varicose dilatation of the veins—consists in placing the extremity in a properly elevated position, enveloping it in a moist dressing covered with rubber tissue, and, in addition, rubbing in mercurial ointment. This rubbing in or, more correctly, inunction of mercurial ointment for phlebitis must be done with the greatest caution and by gentle strokes of the hand, so as not to loosen any thrombi and have them carried off into the general circulation, as sudden death may result from cerebral embolism, or from the lodgment of an embolus in the pulmonary artery. By this treatment the local disease and the fever, when the latter exists, are caused to disappear; the cord-like veins becoming softer after the lapse of about six to eight days, and finally assuming, by degrees, a perfectly normal character. In such cases the phlebitis or the periphlebitis, whether there has been a thrombus formation or not, resolves to a complete *restitutio ad integrum*. If an abscess develops, the pus should be let out as soon as possible by an incision. A permanent occlusion of the vessel sometimes follows the organisation of a thrombus in a vein; this is particularly apt to happen in varicose veins of the leg. The so-called phleboliths (vein stones) result from calcification of venous thrombi. The manner in which thrombi develop, and the changes which occur in them, have been described on pages 290–294.

§ 70. **Cellulitis.**—By cellulitis is meant an inflammation of the soft parts which has a tendency to go on to suppuration, and is particularly liable to be located in the subcutaneous cellular tissue, or more deeply in the *intermuscular* cellular tissue, or beneath fascia, in the sheaths of tendons, in the periosteum, etc. We distinguish clinically two principal classes—the circumscribed and the diffuse. The former remains more or less limited to the neighbourhood of the original start-

ing-point of the inflammation, while the latter has a marked tendency to spread and become a progressive process, the worst form of which is the very acute septic phlegmon; the inflammation sometimes manifests a tendency to spread with incredible rapidity.

It is not always plainly visible open wounds, or large recent injuries, which give rise to the cellulitis. Often enough it is an insignificant, perhaps already healed, abrasion of the epidermis near the nail, such as a scratch or a needle prick, which forms the starting-point for a spreading inflammation. Not infrequently, the cellulitis develops at some spot widely removed from the point of inoculation, from which the bacteria have been carried off in the lymph channels, finally lodging in some suitable locality, a lymph gland, for instance, where they grow and develop. The cellulitis which used to be called spontaneous in its origin does not exist. There is always an infection by bacteria,

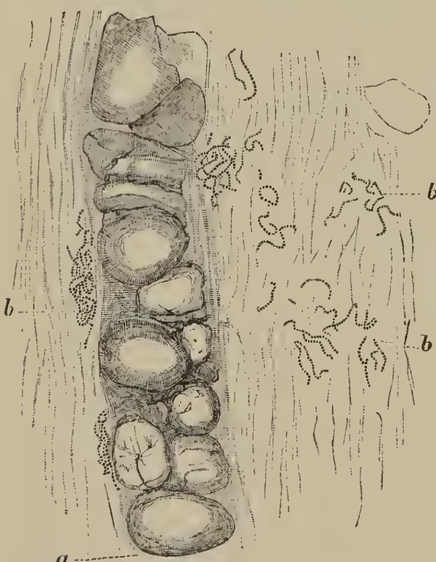

Fig. 262.—Streptococcus of progressive tissue necrosis in mice (Koch); *a*, cells of the cartilage in the ear; *b*, streptococci. × 700.

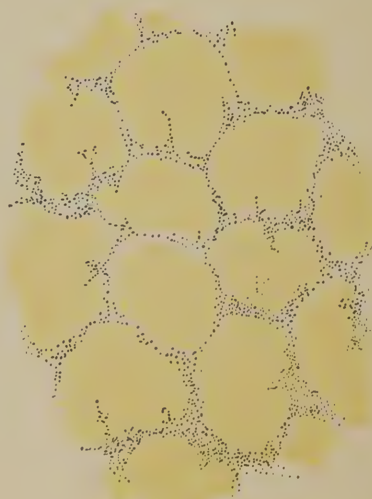

Fig. 263.—Intermuscular phlegmon of the forearm: streptococcus pyogenes between the muscle bundles; stained with gentian violet (after Gram). × 250.

or by the products of their metabolism (staphylococcus pyogenes aureus, streptococcus pyogenes, the bacillus of malignant œdema, less often other pus cocci).

The Micro-organisms found in the Different Forms of Cellulitis; Pus Cocci.—Cellulitis is most frequently excited by the staphylococcus pyogenes aureus and the streptococcus pyogenes, though there are sometimes found other pus cocci, such as the staphylococcus pyogenes albus, the micrococcus pyogenes tenuis, the bacillus pyogenes fœtidus, the bacillus pyocyaneus, etc. Occa-

sionally there will be found only a relatively small number of cocci in the inflammatory collections, the tissues being caused to necrose extensively by the chemical products of the bacterial metabolism (Fig. 262). Again, in other cases, the cocci will be present in vast numbers (Fig. 263). The cellulitis excited by the streptococcus is characterised generally by a marked tendency to spread with great rapidity.

Bacillus of Malignant Œdema.—The worst forms of cellulitis, the so-called acute malignant œdema, progressive gangrenous emphysema (Pirogoff's acute purulent œdema, Maisonneuve's *gangrène foudroyante*), are excited by a specific bacillus first identified by Robert Koch. These little rods are probably identical with the *vibrions septiques* found by Pasteur in septicæmia. In man, malignant œdema occurs, for instance, in conjunction with a compound (open) fracture which does not receive aseptic treatment, or from any wound not aseptically treated. It is characterised by an extensive emphysema (evolution of gas) and by decomposition of the soft parts, and it almost always terminates in death after the lapse of a few days. The bacillus of malignant œdema is very apt to be found in the superficial strata of garden earth, in the dust collecting in the cracks of a floor, in all sorts of decomposing matter, in dirty water, etc. It is more slender than the

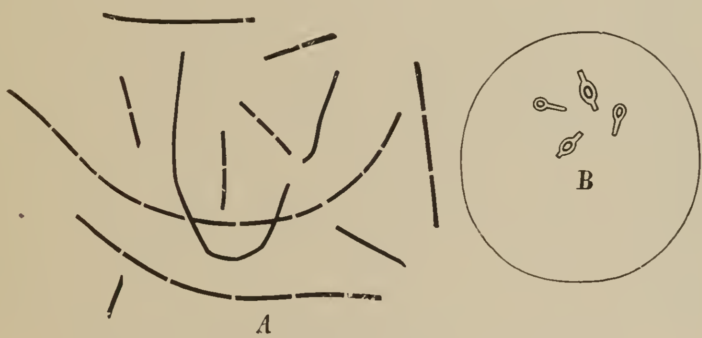

Fig. 264.—*A*, bacillus of malignant œdema. *B*, spore-formation.

anthrax bacillus, being 3·0 to 3·5 μ long and about 1·0 μ broad; it has pointed or rounded ends, and often forms long filaments which may have different crooks or bends (Fig. 264, A). These bacilli are capable of very active movement, and possess cilia on the sides, which can be demonstrated by means of Löffler's method of staining. Spores make their appearance in the cultures by the end of the first day, forming best at a temperature of 37° C. (98·6° F.), (body temperature), in which they grow very rapidly, more slowly at ordinary room temperatures. When developing spores, the bacilli enlarge at one end or in the middle (Fig. 264, B). The œdema bacilli are strictly anaërobic, and can only be cultivated in an atmosphere free from oxygen. On gelatine plates the colonies form small shining knobs containing fluid, and the gelatine is liquefied. On agar plates they form rough, matted clusters with an ill-defined border. Puncture cultures in agar-agar, to which should be added one to two per cent. of grape sugar, develop in diffuse cloudy groups (Fig. 265). Cultures in blood serum show a homogeneous

cloudiness in the line of the puncture. In the interior of a boiled potato the bacilli can be made to grow at a temperature of 38° C. (100·4° F.), and after several days the potato will be found riddled with a network of bacilli. The bacilli can be stained by all the aniline dyes, and will then frequently present a granular appearance. Gram's double stain cannot be used. If 0·1 to 0·3 cubic centimetres of a bouillon culture is injected into the subcutaneous tissue of mice and guinea-pigs, the animal thus inoculated will die in eight to fifteen hours. Upon post-mortem examination there will be found starting from the point of inoculation an extensive subcutaneous œdema, the fluid of which it consists being of a reddish colour and full of bacilli, with bubbles of gas scattered here and there. The bacilli will be found located principally in the serous cavities and in the fluids contained in the different organs. Guinea-pigs inoculated with the peritoneal fluid taken from such an animal will die very quickly. The bacilli can only be demonstrated in the blood several days after death. If bouillon cultures are kept for ten minutes at a temperature of 115° C. (239° F.), or if they are filtered first through porcelain, and then about 100 cubic centimetres of the fluid rendered germ-free in either way are injected at three successive periods into the peritoneal cavity of a guinea-pig, the animal will be rendered immune from subsequent inoculations with the bacilli themselves. In other words, by injecting the products of the metabolism of the bacilli, the animals can be made unsusceptible to the bacilli.

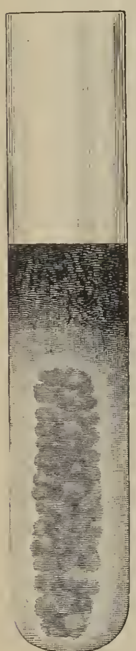

Fig. 265.—Pure culture of the bacilli of malignant œdema. Agar-indigo-sodium sulphate.

Septic Emphysema due to the Bacillus Coli Communis.—In a case of fatal septic emphysema in Gussenbauer's clinic, Chiari found that the bacillus coli communis was the cause of the disease. Chiari attempted to excite a disease analogous to the "septic emphysema" in man with its gas formation, by injecting these bacilli into animals, but all his attempts failed. He could not bring about gas formation, though he made intravenous, intraperitoneal, and subcutaneous injections. The animals died from septicæmia, and the bacilli taken from their dead bodies and isolated in pure cultures evolved gas in considerable quantities.

Symptoms of a Circumscribed Cellulitis.—The symptoms of a more or less circumscribed cellulitis vary with the latter's situation; the more superficial the inflammation is, the plainer are the manifestations of the beginning cellulitis. In a superficial cellulitis, involving the skin and subcutaneous cellular tissue, the affected skin area is red and swollen, it feels hot, and is painful upon pressure. The skin is tense with œdema and cannot be lifted from the underlying parts. The infiltration feels hard at first, but subsequently, with the onset of suppuration, it becomes soft and doughy. Resolution of the inflammation without suppuration is a very rare occurrence. When the transition to pus has taken place, when an abscess is present,

the affected area fluctuates—i. e., by alternating pressure made with both index fingers, the pus is caused to "fluctuate" or take on a wave motion, as any fluid will do when set in motion in a cavity with yielding walls. The pus either forces its way to the surface through the skin, which undergoes a gradual thinning process, or it is evacuated by an incision. The longer the suppuration is allowed to continue before being permitted to escape externally the more apt is the pus to burrow or extend to the parts in the neighbourhood of the abscess. In this way a spreading cellulitis dangerous to life may originate from a circumscribed cellulitis or suppuration.

If a circumscribed cellulitis is deeply situated at the outset, there is but little change in the skin, and neither swelling nor redness will be present, and only when the deep process draws near to the surface of the body will any of the above-described manifestations of its presence be revealed, the first being pain on pressure and œdema of the skin.

In the neighbourhood of the circumscribed cellulitis there will be necrosis of the skin, and particularly of the fascia, tendons, tendon sheaths, muscles, and bones, in proportion to the amount of inflammatory infiltration and the ensuing suppurative breaking down. This death of tissue will be the more easily prevented or limited the earlier incisions are made, and the cavity washed out with antiseptic solutions of bichloride of mercury (1 to 1,000–2,000) or of carbolic acid (three per cent.). Every cellulitis which is not recognised early in its course may not only lead to extensive suppuration, with a proportionate destruction of tissue, but may even cause the death of the patient from a fatal general systemic infection—pyæmia, for instance—if the inflammatory elements are carried off and spread throughout the body by the blood-vessels. Under such conditions inflammation of the lymph channels (lymphangitis) and inflammation of the arteries and veins (arteritis, phlebitis) may be excited, with the formation of suppurating thrombi in the veins, also swellings and abscesses of the lymph glands, and metastatic abscesses in the internal organs, etc. Accompanying every circumscribed cellulitis there will be fever, the intensity of which will vary according to the virulence of the poison.

Whitlow or Paronychia.—Paronychia or whitlow is, for the most part, at the outset a circumscribed inflammation of the subcutaneous cellular tissue of a finger, particularly on its palmar aspect, though it may begin in the palm of the hand. Paronychia may appear to begin spontaneously, but usually results from some injury, which may be only a very small abrasion of the epidermis. It is most apt to occur in individuals who are constantly receiving superficial injuries of the skin on their fingers, or in those who, like physicians and anatomists, frequently handle decomposing substances and thus infect themselves. The inflammation is more likely to

spread into the deeper parts than to come to the surface; but there are also superficial forms of paronychia which spread very rapidly. The pain is usually very severe, as great pressure is exerted upon the nerves in the tense tissues. Death of tissue is a common occurrence as a result of the closure of the capillaries and small veins and arteries by pressure. If the paronychia extends to the tendon sheath, it usually spreads rapidly on account of the looseness of the tissue. From a neglected paronychia or whitlow, resulting in a spreading cellulitis, many a patient has suffered a serious loss of function of the hand, or the hand itself, or the forearm, or the whole arm, while the lives of some patients have not been saved even by an amputation.

Symptoms of the Diffuse Spreading Cellulitis.—The *diffuse spreading cellulitis*, formerly called diphtheritis of the cellular tissue, is usually very acute and much worse than the circumscribed variety. Like the latter, it is sometimes caused by very trifling injuries, such as a needle prick, or by a wound of the soft parts of a bone, or of a joint, which is not brought soon enough under the protection of an antiseptic treatment. The local manifestations are at the outset the same as those of a circumscribed cellulitis. In many instances the disease begins with a severe chill and a proportionately high fever. The changes in the overlying skin may at first be very slight, and in fact it is not even reddened in the very dangerous deep forms of cellulitis which spread very rapidly. Just these cases are the ones so often unrecognised by the beginner. The process spreads quickly in the deep subfascial cellular tissue, and may terminate in a relatively short time in a fatal systemic infection. But in a spreading diffuse cellulitis, the skin is generally involved, and has a dark or bluish-red colour, and not infrequently the epidermis is elevated by blebs; there is also an inflammatory infiltration of the skin which may make it as hard as a board. If the cellulitis is deeply situated, the skin feels more doughy and œdematous. The pain is very marked and usually there is a high fever. Not rarely the course of the disease is so acute that even after the expiration of four to five days disarticulation of the extremity may be necessary, or it may even then be too late to prevent the death of the patient from the general systemic poisoning. This form of septic, spreading cellulitis with high fever, extensive gangrenous destruction of tissue, and death by general systemic poisoning, has a very unfavourable prognosis, and has received the names of malignant œdema, progressive gangrenous emphysema, acute purulent œdema (Pirogoff), and *gangrène fondroyante* (Maisonneuve). These dangerous forms of septic cellulitis are excited by the bacillus pictured in Fig. 264.

If the diffuse inflammatory infiltrate in the subcutaneous cellular tissue, in the subfascial and intermuscular tissue, the sheaths of the tendons, and in the periosteum, is changed into pus and softens, the

pain decreases, and there follows an extensive necrosis of the infiltrated tissues, including the skin, subcutaneous cellular tissue, fascia, muscles, tendons, and bone. Large sacs are formed filled with pus, the skin is lifted from the underlying parts, and joints are opened. As a result of the decomposition of the pus, emphysema, or the formation of gas, takes place, and this may be so marked that a peculiar crackling can be obtained on palpation, and a more or less tympanitic resonance will be elicited on percussion. If the diffuse cellulitis does not carry off the patient by general sepsis, the subsequent course of the disease is often very tedious, consisting in the gradual sloughing away of the gangrenous parts, and the proportionate formation of cicatricial contractures in the skin, tendons, muscles, joints, etc. The patient may also die in this stage from pyæmia, marasmus, parenchymatous degeneration of the internal organs, or from extension of the inflammation to vital parts—for example, from the skull to the meninges. Death may also result from hæmorrhage following suppurative perforation of the arteries or large veins, etc.

Prognosis of Cellulitis.—The *prognosis* of *cellulitis* varies greatly, depending upon the situation of the disease, the extent of the inflammation, and the kind of bacteria which excites the process. A cellulitis of the scalp, for instance, is a serious matter, from the danger of the inflammation spreading to the cranial cavity. In general, the superficial forms of cellulitis are not dangerous, while the deeper, subfascial, spreading forms, by causing general systemic infection, involve the greater risk to life the longer they remain unrecognised. The worst forms are those with progressive emphysema, caused by infection with the bacillus of malignant œdema; they often terminate fatally within a few days, before the local manifestations of the process become plainly marked. The prognosis of the others may be inferred from what has been said of them.

Treatment of a Cellulitis.—The treatment of every cellulitis is practically the same, whether the inflammation is circumscribed or spreading. Much time used to be lost by the employment of cataplasms to obtain resolution of the inflammation. The knife should be used as soon as possible, and free incisions made to diminish the inflammatory tension of the tissues and to allow the pus to escape, after which the entire focus of the inflammation should be disinfected by one-tenth-per-cent. solutions of bichloride of mercury, or by three- to five-per-cent. solutions of carbolic acid. We do not wait till suppuration and breaking down of the tissues have taken place, but we immediately make an incision into the region where there is the most pain or the most pronounced swelling and inflammatory infiltration, even though there may

be as yet no pus present. If early incisions are thus made it may be possible to prevent death of tissue from taking place, particularly in the tendon sheaths, bones, etc., or at least to limit the amount of it, and cases treated in this manner will heal comparatively the most rapidly. The incisions should not be too small; it is better to make them too free rather than not large enough. The collection of pus should be laid bare throughout its whole extent by long incisions, and any pockets that may be present opened up. If the cellulitis is deep, the incision should be carried through the skin and fascia with the knife, and then the incision should be deepened with a blunt instrument—a closed dressing-forceps, for instance—till finally the bone is reached. In an extensive cellulitis the parts which appear sound must be examined very carefully, to determine whether pus may not have burrowed into or beneath them. After making the incisions the region in which there have been large collections of pus should be washed out vigorously with a 1 to 1,000 solution of bichloride of mercury, or three to five per cent. of carbolic acid. The incisions should be so placed as to facilitate the escape of the pus, which is then provided for by proper drainage (§ 31), or by packing with iodoform gauze, sterilised mull, etc. The best dressing for a circumscribed cellulitis is one which is antiseptic and absorbent—for example, iodoform gauze, sterilised mull and cotton, or pads of moss, jute, etc. Of course, the dressings should not exert any more than moderate pressure, to prevent pus from being forced into the connective-tissue spaces. In cellulitis of the fingers, I prefer to have the first dressings moist rather than dry, and to make use of frequent antiseptic baths, and then, later, to use as dressings ointments of iodoform and boric acid. Poultices, which used to be so much in vogue, should be condemned. Their use has caused much harm. To be able to determine whether there is any burrowing or retention of pus, the dressings must at first be frequently changed, possibly every day, or every second or third day; and not until the wound begins to granulate and suppuration ceases can the dressings be left undisturbed for a longer period. If the suppuration has been extensive, secondary sutures may be of service in hastening the repair after the packing has been removed.

In diffuse cellulitis, with extensive destruction of tissue, long incisions, followed by packing the wounds, are particularly valuable, and this may be subsequently supplemented with advantage by antiseptic washings or permanent irrigation (pages 179, 180). After the gangrenous tissues are cast off and the granulating stage has begun, a return may be made to antiseptic protective dressings of iodoform, oxide of zinc, etc. To shorten the time required by a large granulating wound

to become covered with skin, Thiersch's skin grafts are very useful (see § 42). In the treatment of every cellulitis, it is exceedingly important to secure for the inflamed part a proper position upon splints (§ 53), or in a mitella (Fig. 155), etc. Elevation of an inflamed lower extremity, or vertical suspension of an inflamed hand, has an excellent effect, and sometimes works wonders. In the worst cases of septic cellulitis, amputation or disarticulation of the affected extremity will sometimes be found necessary in order to save the life of the patient. Unfortunately, the operation is sometimes performed too late, when general sepsis is already present.

The after-treatment of the sequelæ of cellulitis, the cicatricial contractures, necrosis of bone, etc., is conducted on the lines laid down for these conditions in another chapter (Contractures, Necrosis of Bones).

Phlegmasia Alba Dolens is an inflammation of the leg, rarely of both legs, running a slow course, with œdema and pain, principally due to venous thrombosis and occurring mostly in lying-in women and in cachectic patients (tuberculosis, carcinoma, etc.). The phlegmasia alba dolens of puerperal women is usually caused by the extension of an infectious inflammation of the pelvic connective tissue (parametritis), which ordinarily takes place in the second week after confinement. It terminates either in absorption of the inflammatory infiltrate, or in suppuration or gangrene, and rarely in death, which is then apt to be due to embolism or sepsis. The phlegmasia alba dolens of cachexia is mainly the result of venous stasis, caused by defective cardiac and pulmonary activity. It rarely goes on to suppuration.

§ 71. **Erysipelas.**—By erysipelas (from ἐρυθρός, red, and πέλλα, skin) is meant a spreading inflammation of the external cutaneous covering of the body, or rather of its smaller lymph channels, and of those of the subcutaneous cellular layer, caused by bacteria (streptococcus). It is a specific dermatitis, characterised (1) by a more or less rapid, for the most part, continuous extension along the surface, less often into the deeper parts; (2) by a toxic diseased state of the general system (intoxication fever) going hand in hand with the local inflammatory disease; and (3) generally by a complete *restitutio ad integrum* of the local inflammation, at least in the typical and uncomplicated cases. Gangrenous destructive processes, abscess formation, etc., take place in exceptional cases, and are then complications of the local disease.

Etiology of Erysipelas—Streptococcus of Erysipelas.—The micro-organism of erysipelas is generally a streptococcus (Figs. 256, 257, and 266) which was first obtained in pure cultures by Fehleisen. If man or animals are inoculated with this streptococcus true erysipelas will result. I have produced in animals (rabbits) true erysipelas by inocu-

lating them with the contents of erysipelas blebs. The streptococcus erysipelatis is found almost everywhere, particularly in the air of surgical wards (Eiselsberg).

Tissues affected by this disease, when examined by the microscope, reveal the erysipelas coccus, especially in the lymph spaces of the skin and subcutaneous cellular tissue, but it is usually not to be found in the blood-vessels. Not infrequently there will be large groups of the streptococcus present. Recent investigations have demonstrated that Fehleisen's erysipelas coccus is identical with the streptococcus pyogenes described on page 323, and neither coccus can be distinguished from the other in any way. The description of the erysipelas coccus is given on page 323 (streptococcus pyogenes). In erysipelas, as mentioned before, the streptococcus grows mainly in the smaller lymphatics of the skin and subcutaneous cellular tissue, while in circumscribed suppurative processes the coccus is found more in the tissues themselves. Suppuration and abscess occur in erysipelas, in all probability, when the streptococci develop in large numbers in the tissues outside of the lymph channels, or when there is a mixed infection—in other words, when the staphylococcus pyogenes aureus or other pus cocci are present in addition to the streptococcus pyogenes. The erysipelas which is complicated by gangrenous destructive processes is also probably caused by a mixed infection. Jordan and others maintain that erysipelas can also be caused by the staphylococcus, thus making erysipelas, from a bacteriological standpoint, a non-specific disease as regards its etiology. Kaltenbach and others have made the interesting observation that erysipelas or the erysipelas coccus can be transmitted from the mother to the fœtus *in utero*. Bostroem has also demonstrated the fact that erysipelas cocci may enter the blood. He saw an acute catarrhal pneumonia develop in conjunction with a facial erysipelas, and after death the lymphatic vessels in the lungs were found filled with streptococci. The systemic intoxication, the fever in erysipelas, is, in the main, the result of the entrance into the circulation of the metabolic products of the streptococci. The streptococci themselves cannot, as a rule, be demonstrated in the blood.

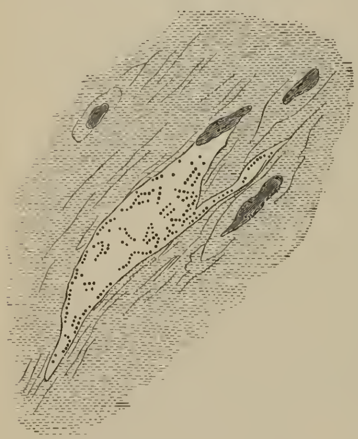

FIG. 266.—Streptococci of erysipelas. × 700. Section through a lymph vessel of the skin (Flügge).

Erysipelas of Mucous Membranes.—Erysipelatous inflammations occur not only in the external cutaneous coverings of the body but also in mucous membranes, especially the adjoining mucous membranes of the nose, mouth, and their adnexa, the trachea, the female genital tract, and the rectum. A cutaneous erysipelas may have involved these mucous membranes in its course, or, on the other hand, an erysipelatous inflammation may originate in the mucous membranes and extend from them to the skin in the form of a true erysipelas. Erysipelas is a true infectious disease of wounds—i. e., it originates from some interruption of continuity which may be of the most insignificant character. Erysipelas does not originate spontaneously in the sense that used to be understood by the term. But there are forms of erysipelas—for instance, in systemic pyæmic poisoning—which have a metastatic origin. From any cellulitis a capillary lymphangitis, in other words, an erysipelas, may begin if the streptococci find lodgment and undergo subsequent development in the lymphatics of the skin and subcutaneous cellular tissue.

Location of Erysipelas.—As regards the localities affected by erysipelas, it occurs most frequently upon the face, often starting from some superficial abrasion of the skin, an ulcer in the nose, etc. Sometimes erysipelas cases occur in such numbers in some particular locality or in some hospital that the disease becomes epidemic, or, rather, endemic. Like every infectious-wound disease, erysipelas has become less common since the general use of antiseptic methods, and by strict asepsis it is possible to absolutely prevent an outbreak of erysipelas in a recent non-infected wound.

Symptomatology of Erysipelas.—The clinical picture of true, uncomplicated, cutaneous erysipelas is in the majority of instances characterised by the sudden occurrence of a rapidly rising, generally severe febrile movement which goes hand in hand with the erysipelatous inflammation of the skin. Subsequently there is just as rapid a defervescence, the temperature falling to the normal or below it when the local erysipelatous inflammation approaches its termination.

At the beginning of a true cutaneous erysipelas there will be noted the gradual appearance of a diffuse, somewhat elevated reddening of the skin in immediate proximity to some small or large, recent or old, granulating or ulcerated wound of the skin. Frequently no wound of the skin can be made out at all ; a slight cutaneous abrasion may have already healed. In other cases the point at which the streptococci of erysipelas have entered may be found in some adjoining mucous membrane or in some widely removed region. The redness is at the outset apt to be in spots, which often appear as though the lymphatic network

had been injected with some red material. It was mentioned before that the streptococci of erysipelas spread mainly in the lymph channels of the skin and subcutaneous cellular tissue. The original spots very soon coalesce, forming an even, diffuse redness. Sometimes the reddening of the skin may start, as has been said, at a greater or less distance from a wound or interruption of continuity in the epidermis, and under such conditions the red stripes of a lymphangitis will connect the wound, on the fingers or toes, for instance, with the commencing red spot on the arm or on the leg or thigh (see Lymphangitis, § 68). The erysipelatous redness and swelling extend steadily now in this and now in that direction; they migrate, and may involve large areas of skin, or even the entire body, depending upon the intensity of the disease. The areas of skin first affected begin to turn pale again after the lapse of about two to four days, and sometimes earlier. In the regions where the skin is firmly attached to the underlying parts, to the bones or fascia, the erysipelas is apt to come to a standstill. Erysipelas generally extends progressively, though in cases of rapid, wandering erysipelas the disease may sometimes skip over an area of skin—for instance, in erysipelas of the foot—a large erysipelatous patch may suddenly appear in the region of the knee or thigh, and then soon afterwards coalesce with the patch on the foot. Under these conditions the two foci of erysipelas are usually connected by red stripes (lymphangitis). Occasionally, especially when occurring as a complication of pyæmia, there will be observed the so-called erratic, or, better, multiple erysipelas, which makes its appearance by metastasis upon different parts of the body.

The erysipelatous reddening of the skin ordinarily exhibits different tinges, varying from a bright to a dark red colour. In weak individuals, or when complicating pulmonary or cardiac affections (disturbances of circulation), or just before death or as the first stage of local death of tissue, the erysipelas has more of a bluish colour.

If there are gastric complications, or if occurring in drunkards, the cutaneous redness occasionally assumes a yellowish shade.

The swelling in an area affected by erysipelas is usually uniform, and the pain in the majority of cases is slight, but is increased on pressure with the finger. Wherever the skin is superimposed upon distensible loose tissue there will be a marked erysipelatous exudation, as in the scrotum, penis, the female genitals, the eyelids, or the lips. As a result of the saturation of the superficial layers of the cutis with serum during the course of an erysipelas there will often develop smaller or larger blebs, at the outset containing a clear serous fluid, and later, for the most part, pus. The blebs, as a usual thing, very soon dry up and form crusts.

The extension of the erysipelas takes place now from this and now from that border; it strides forward like a fire; it wanders, and hence the name erysipelas migrans or ambulans. For several days the erysipelas may spread in some particular direction, and then the process ceases and begins to spread from another border. It acts like a fire which cannot be controlled and which continues to burn wherever there is food for it, and the flame may suddenly again break out in a region where it seemed quenched. Pfleger thinks that the spread of erysipelas in a particular direction depends upon the course of the linear furrows of the skin. The rapidity with which the erysipelatous inflammation extends varies greatly, moving forward sometimes one to two centimetres within twenty-four hours, again four to eight or fifteen to twenty centimetres and more. Eventually, in the great majority of cases, the inflammatory redness and swelling terminate in a complete *restitutio ad integrum;* but suppuration may occasionally take place and multiple abscesses may form, or as a result of very pronounced swelling or from the extension of the disease to the deeper parts the erysipelas may become complicated by phlegmonous changes, with extensive or limited death of tissue (erysipelas phlegmonosum, erysipelas gangrenosum). A process the reverse of this sometimes takes place—i. e., a deep-spreading cellulitis may come to the surface and run its

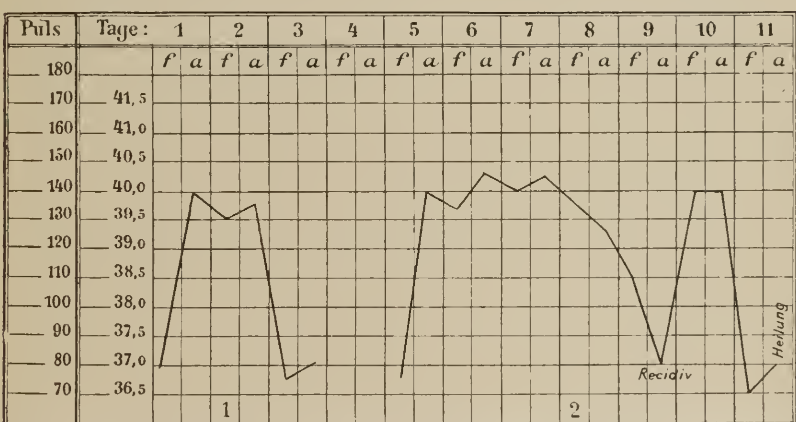

FIG. 267.– 1, Temperature-curve of an erysipelas lasting two days with a sudden typical fall of temperature; 2, temperature-curve of an erysipelas with temporary fall of the temperature followed by a relapse of the erysipelas; recovery.

course as an erysipelas of the skin. It has already been stated that in the complicated cases of erysipelas there is usually a mixed infection, due to the streptococcus and other bacteria.

The *general constitutional symptoms* correspond to the intensity and extent of the local process. The rise of temperature begins, as a

rule, suddenly and rather violently, with one or more chills, and subsequently, when the erysipelas ceases, the temperature returns to the normal with equal rapidity. At the height of the disease the temperature generally rises to about 40° C. (104° F.) or more, and in exceptional cases it may reach 42° C. (107·6° F.). The fever may have either a continuous, a remittent, or an intermittent type (see pages 258, 260). Very often there will be pronounced gastric symptoms; the regions over the liver and stomach are tender on pressure, there is total loss of appetite, with nausea or vomiting, the thirst is ordinarily excessive, the tongue is heavily coated, dry, etc. The spleen is frequently much swollen; sometimes there is pain in the region of the kidneys, the urine is generally dark coloured, and may contain albumen, blood, bile pigment, and micrococci, and its quantity is diminished. If the erysipelas has a fatal termination, death is either the result of the general systemic poisoning by the products of the metabolism of the bacteria, or it is caused by some local complication, such as the extension of the erysipelas to some vital organ, to the cranial cavity, for example. Occasionally, if the erysipelas is protracted for a great length of time, the gradually increasing exhaustion of the patient may be the direct cause of death, which may take place suddenly after convalescence has begun.

There is no typical time of duration for an erysipelas, and recurrences are very common. The erysipelas may appear to have come to an end and then it will suddenly start up again. Its duration varies between hours and weeks. There are well-marked cases of erysipelas lasting twenty-four hours, and even a less time, and others which continue for a week, with now greater and now less intensity, and which may eventually involve the entire body, and possibly attack the same locality several times. The average duration of erysipelas amounts to about six to eight to ten days, but, as Billroth says, it is, as a general thing, unusual for the disease to continue more than fourteen days.

Habitual Erysipelas.—Many individuals are subject to what is called habitual erysipelas, a form of the disease recurring more or less periodically upon some particular portion of the body, most commonly the face, and resulting very often from a chronic nasal catarrh which is accompanied by ulceration.

Complications of Erysipelas.—As complications of erysipelas, there may be marked disturbances of the central nervous system due to the high fever or general systemic poisoning, particularly in an erysipelas of the head, which gives rise to meningitis. When the latter condition arises, there will be at the outset very marked symptoms of irritation, headache, vomiting, delirium, stupour, and finally convul-

sions. Exceptionally, even when convalescence has begun, and after the erysipelas and the fever have almost completely vanished, there will be observed in excitable persons a state of collapse with delirium of a more or less maniacal nature, accompanied by illusions and hallucinations of sight and hearing, the so-called collapse delirium. This temporary aberration of mind lasts usually only a few days. More rarely there are paralyses of the peripheral nerves as a result of central disturbance, or from peripheral neuritis caused by the erysipelatous inflammation. Leyden and Renvers observed an ataxia of the lower extremities which lasted a considerable time and followed the extension of an erysipelas of the head on to the back.

The most important of the local complications which may arise are suppuration and gangrene, and the combination with an inflammation of a phlegmonous character. The number of multiple abscesses which may make their appearance in the stage of convalescence is comparatively large—twenty to thirty or more. Landouzy saw as a result of an erysipelas involving the face, hairy portion of the scalp, the neck and back, sixty-nine abscesses, and some of them in areas which had not been affected by the erysipelas. Occasionally the suppurative process is more diffuse in its nature, and extends inwards, leading to suppuration of the muscles, tendon sheaths, joints, etc. (erysipelas phlegmonosum). The erysipelatous joint suppurations appear either at the outset and run a very acute course, or they first make their appearance during convalescence. Mention should also be made of phlebitis, lymphadenitis, and abscesses of the lymph glands. The lymph glands are usually swollen at an early stage of the disease. Gangrenous processes occurring in a true erysipelas are rare and generally of limited extent, and only extensive and severe when the erysipelas is complicated by changes of a phlegmonous character (*E. gangrenosum*). Amongst the other local complications which may arise, the diseases which may affect the eye should be included, such as impaired vision, rarely temporary blindness, panophthalmia with atrophy or suppuration of the eyeball, particularly when a facial erysipelas spreads to the cellular tissue of the orbit, iritis, ulcerative processes of the cornea, retinitis, and optic neuritis with atrophy of the optic nerves. There may also be catarrhal and suppurative processes affecting the ear, inflammation and suppuration of the parotid gland, dysphagia, and sometimes changes in the pharynx simulating diphtheria. Occasionally an inflammation of the lungs is produced (erysipelatous pneumonia). Pleurisy and cardiac affections (pericarditis, endocarditis, and myocarditis) are not common. Amongst the gastro-intestinal complications which may arise are ulcerations of the small intestine, and

transitory hyperæmia of the intestinal mucous membrane accompanied by bloody diarrhœa. A similar condition may occur in patients who have received burns, and I have seen it in conjunction with extensive carbolic erythema (see page 154). The liver and spleen only exceptionally give rise to complications. Jaundice due to gastritis may occasionally be present, but hæmatogenous jaundice can also occur in severe cases of erysipelas as a result of the poisoning of the blood by the products of the bacterial metabolism, and this is usually a precursor of speedy death. Nephritis is often present as a complication, but it is generally of a temporary nature; only in very exceptional cases is the acute erysipelatous nephritis so marked as to cause uræmia. The latter is particularly dangerous when occurring in individuals already affected by kidney disease before they were attacked by erysipelas. Erysipelas is sometimes complicated by pyæmia and septicæmia (see §§ 74 and 75), and occasionally, as has been stated, erysipelas will occur in the course of a pyæmia.

Behaviour of the Wound in Erysipelas.—The interruption of continuity from which the erysipelas has sprung seldom manifests any complications. The healing of the wound *per primam intentionem* is not often disturbed; but the healing may sometimes be only apparent, and the wound may only unite superficially, while in its deeper parts there will be a retention of the secretion or of pus. A granulating wound will often exhibit a dry or dirty appearance, and may be covered by a peculiar croupous diphtheritic membrane. Erysipelas has occasionally been complicated by hospital gangrene (§ 72), especially before antisepsis was introduced.

The Healing Effect of Erysipelas (*Curative Erysipelas*).—Great interest attaches to the influence exerted by an intercurrent erysipelas of the skin upon new growths, particularly those of a lupoid or syphilitic nature, with or without ulceration, and also upon tumours, such as sarcoma and carcinoma. It has been noticed that the above-mentioned formations may permanently disappear, and that ulcers of long standing and chronic skin diseases, which resisted every kind of treatment, have improved and were healed after an erysipelas had passed over them. The French have given the appropriate name of *erysipèle salutaire* to an erysipelas which acts in this way, and numerous observations are recorded in literature upon the healing powers of erysipelas for all sorts of diseases. W. Busch, in particular, has recorded some very remarkable facts relating to the curative effect of erysipelas upon large tumours (sarcomata, lymphosarcomata), and he showed that the tumours underwent a rapid and extensive fatty metamorphosis, and could thus be absorbed and completely disappear. The curative power of erysipelas

over tumours has been repeatedly made use of artificially for the purpose of destroying inoperable new growths. If inoculation of erysipelas is to be practised on any patient, it must be borne in mind that the course of this disease cannot always be held under control, and that there is a possibility of a fatal termination, as many cases testify. And although it is certainly justifiable to produce erysipelas artificially for the purpose of curing an inoperable tumour, the patient should always be informed beforehand of the danger of the treatment. P. Bruns has recently made a critical investigation of the curative effects of erysipelas upon tumours, and succeeded in collecting twenty-two cases from literature. There was a complete and permanent cure in three cases of sarcoma, in two cicatricial keloids, and in a few lymphomata. In Bruns's own case a perfect recovery was brought about from a recurring melano-sarcoma of the mamma. In one case, observed by Janicke and Wisser, in which erysipelas inoculation was practised for an inoperable carcinoma of the breast, it could be demonstrated with the microscope that the erysipelas cocci actually destroyed the cancerous cells. Consequently it is possible for erysipelas to cure a carcinoma.

Ferret observed the complete absorption within six days of the callus surrounding an already united fracture of the thigh, so that the fragments again became as freely movable as at the time of fracture. There is one other curious fact ascertained by Emmerich, Pawlowsky and Di Mattei which should be mentioned in this connection. If rabbits and guinea-pigs are inoculated with erysipelas, during the ensuing three to ten days they will be unsusceptible to (immune from) anthrax; but after the lapse of this period the system is so weakened by its conflict with the erysipelas cocci that when the animal is infected by anthrax for the second time it succumbs more easily and rapidly than it normally would; in other words, after the lapse of this period the animal is no longer immune from anthrax.

Erysipelatous Inflammations of the Mucous Membranes.—Inflammations analogous to cutaneous erysipelas occur, as has been stated, in the mucous membranes which adjoin the skin, and consequently in the oral cavity and its adnexa (nose, pharynx, larynx), in the female genital tract, and in the rectum. Erysipelatous wandering pneumonia is described in books on internal medicine.

Diagnosis of Erysipelas.—The *diagnosis* of the ordinary cutaneous *erysipelas* is very simple in typical cases, and can hardly cause any trouble. The gradually spreading local redness and swelling of the skin and the accompanying fever are so characteristic that there can scarcely be any confusion, even with the exanthemata. Erythema bears the closest resemblance to erysipelas, but in erythema there is

usually no fever, and the swelling and pain are not nearly so pronounced as in erysipelas.

Prognosis.—In general, the *prognosis* of erysipelas is not unfavourable, but in no case of this disease, no matter how mild it may seem, can we be certain of a satisfactory termination. There are many circumstances which affect the prognosis of an erysipelas, particularly its location, the constitution and age of the patient, the complications which may arise, the intensity and duration of the local disease, and of the fever, etc. The more extensive the inflammation the higher the fever, and the longer it lasts so much the worse is the prognosis. The mortality given by various authors differs very much, the average being about eleven per cent.

Treatment of Erysipelas.—A great number of remedies have been employed for erysipelas, and the fact that the treatment varies so much shows that nothing is entirely satisfactory; and it is my opinion that, as yet, we have no very reliable and effective method of treatment. Since the disease has no typical duration, it is very natural that mistakes should be made in regard to the curative power of this or that remedy.

The best way of preventing erysipelas consists in treating every interruption of continuity, whether recent or old, large or small, upon antiseptic or aseptic principles; and whenever a dressing is changed it should be done with a careful observance of the rules of antisepsis.

I believe—and my opinion is sustained by the experiments of Robert Koch—that bichloride of mercury is the most reliable antiseptic for use in dirty infected wounds, to prevent infectious-wound diseases. Fehleisen states that cultures of the erysipelas coccus are completely destroyed when subjected for ten to fifteen seconds to the action of a 1 to 1,000 solution of bichloride. Erysipelas never occurs after operations which have been performed with the strictest attention to asepsis. We avoid the free use of poisonous antiseptics in performing aseptic operations, though they were formerly much in vogue. They are not necessary if the rules of asepsis are understood and followed—in other words, if everything which comes in contact with the wound is made absolutely germ free (sterilised). When the erysipelas has broken out, the treatment should be directed against the general febrile disturbance and the local disease. The treatment of the fever has been discussed in § 62.

The treatment of the local disease consists in placing the affected portion of the body in a suitable position, and in the application of ice, particularly if the erysipelas involves the head. By painting the erysipelatous area with oil and covering it with cotton the tension and pain will be lessened.

It is an excellent plan to use the parenchymatous injections of a two- to three-per-cent. solution of carbolic acid at the margins of the inflamed district, which Hueter has recommended, particularly in the beginning of the erysipelas. The contents of three to five hypodermic syringes filled with this solution are injected into the sound skin immediately adjoining the erysipelatous area; and after the acute stage of the inflammation has passed, or while the disease is spreading, these injections are repeated once or twice. Subcutaneous injections of bichloride of mercury are also exceedingly good. Petersen has employed salicylic acid injections with successful results; others have done the same with cocaine, and Zuelzer has used ergotine (five to eight centigrammes to equal parts of alcohol and glycerine). Estlander recommends subcutaneous injections of morphine, particularly when combined with a daily painting of the diseased area with tincture of iodine. Lücke and others have used inunctions of turpentine with success; it is rubbed into the diseased area of skin two to three to five times a day with a brush or piece of cotton. Strong tincture of iodine can be applied with a brush seven to eight times a day; nitrate of silver (one to four, or eight, or ten) is highly praised; also the application of compresses wet in a three- to five-per-cent. solution of carbolic acid, or in a five- to ten-per-cent. solution of trichlorphenol; fifty to eighty per cent. resorcin ointment may be spread over the affected part, etc. Heppel recommends painting the borders of the erysipelatous area with a ten-per-cent. alcoholic solution of carbolic acid, covering a portion of skin about two inches wide all around the diseased spot. The following methods have also been recommended for treating the disease locally: Covering the erysipelatous area of skin with ammonium sulpho-ichthyolicum mixed with equal parts of lard, or with ichthyol and vaseline (equal parts), and placing over this absorbent cotton; covering the erysipelatous area close up to the surrounding healthy skin with an ointment of one part creolin, four of iodoform, and ten of lanoline (Koch and Mracek), or with white lead, or with a varnish of linseed oil, over which some water-tight material is applied, etc. Kühnast, from his experiments in Kraske's clinic, recommends multiple scarifications and incisions, followed by irrigation with a five-per-cent. solution of carbolic acid; also the application to the erysipelatous area of compresses wet with a two-and-a-half-per-cent. solution of carbolic acid, the compresses to be changed once or twice a day. Riedel and Classen recommend scarification, particularly at the advancing margins of the erysipelas. Scarifications are exceedingly effective, especially when made chiefly or exclusively in the healthy adjoining skin. Madelung, W. Meyer and others have obtained satisfactory results from scarification and

application of compresses wet in a three- to five-per-cent. solution of carbolic acid or in a 1 to 1,000–3,000 solution of bichloride of mercury. This latter method of treatment is coming more and more into favour at present. Larrey preferred to make linear or punctate canterisations with the red-hot iron, aiming at retaining the erysipelas within the barriers made by the eschars. Wölfler has prevented the spread of an erysipelas by means of the mechanical compression produced by placing strips of adhesive plaster around its borders. For the same purpose Niehans employed collodion, applying the latter around an extremity over a space about two handbreadths in width, thus encircling the extremity with the collodion as with a bandage. Kroell recommends strips of caoutchouc for the same purpose. Winiwarter and Fraipont speak well of the following method of treatment: The part affected by the erysipelas and the wound are soaked for ten minutes in a bath of 1 to 3,000 bichloride, or the latter is used in the form of an irrigation for a longer period of time; the erysipelatous area is then dried, and it and the adjoining healthy skin are covered with tar, over which is applied a dressing wet with Burow's solution (see page 159); then iodoform gauze which has been dipped in a bichloride solution is placed on the wound, and the whole dressing is bandaged lightly in position.

It has been attempted to combat the erysipelatous inflammation by the internal administration of drugs. English surgeons, in particular, give iron internally (liq. ferri chlorat., in large doses, fifteen to twenty drops every hour, or even 2·0 grammes or more); others use liq. ferri sesquichlorati., ten to fifteen drops every two to three hours; ergotine, iodide of potassium, and belladonna have been used for the same purpose. Haberkorn has recently employed with success benzoate of sodium in mucilaginous solutions, or in some effervescing water, in doses of fifteen to twenty grammes a day; no local treatment is made use of. The effectiveness of all internal medication is exceedingly doubtful. Camphor (internally or in the form of subcutaneous injections) has but little value, though it was highly recommended by Pirogoff.

The treatment of the complications, particularly the abscesses, gangrenous processes, and the inflammations of joints, should be conducted on the principles laid down for these conditions. At the time of the outbreak of the erysipelas, or when the case is met with in a later stage, the wound from which the disease starts should be carefully examined and treated antiseptically, and if any blood or pus is held in retention it should be let out by removing a few sutures, by separating the agglutinated margins of the wound, by making incisions, etc.

If it is desired to inoculate an erysipelas for therapeutic purposes

upon an inoperable tumour or other diseases of the skin, it should always be borne in mind that infection by the streptococcus of erysipelas may cause the death of the patient.

Zoönotic Erysipelas—Wandering Erythema (*Erythema migrans*).—The so-called erysipeloid or wandering erythema occurs almost exclusively on the hands, and attacks most commonly individuals who handle all sorts of dead animal substances, dealers in game or fish, cooks, restaurant keepers, butchers, tanners, oyster openers, and those who come much in contact with cheese, herring, etc. The erysipeloid is a disease of wounds which is not very infectious in character, and affects the hands almost exclusively, some infectious substance being inoculated into small wounds. After inoculation there ensues a moderate infiltration of the skin, giving the latter a dark-red discolouration; there is no fever, and the disease spreads very slowly, with an itching, prickling sensation, and it may take eight days to extend, for instance, from the finger-tip to the metacarpus. The reddening of the skin more often occurs in spots; less frequently it is of a diffuse character. It is only very exceptionally that the erysipeloid extends as far as the wrist, and it never reaches the forearm. The disease is often very stubborn and persistent, lasting sometimes three to four to six weeks unless proper treatment is adopted; but in other cases it may disappear spontaneously in one to two to three weeks. Rosenbach found that a coccus-like body was the cause of the erysipeloid; it is larger than the staphylococcus, grows best in gelatine at a temperature of 20° C., forms twisted filaments of varying length, and bears a remarkable resemblance to a form of microbe described by Cohn under the name of cladothrix dichotoma. Rosenbach and Cordua have produced this erysipeloid by inoculations practised on themselves.

The best method of treating the zoönotic erysipeloid consists in cutaneous injections of a three-per-cent. solution of carbolic acid into the inflamed area of skin, and into the healthy skin immediately adjoining its outer borders.

§ 72. **Hospital Gangrene—Wound Diphtheria.**—Hospital gangrene (*Gangræna nosocomialis*), or wound diphtheria, used to be, in the pre-antiseptic era, a very common disease, but if antiseptic treatment is used it never occurs. Hospital gangrene is a local wound disease, always bacterial in its origin, and consists essentially of a gangrenous destruction of the granulations and adjoining tissues. In the days before the dawn of antisepsis it was of very frequent occurrence in many hospitals with bad hygienic arrangements, and was particularly common in conjunction with contused wounds or those in which there was considerable extravasation of blood, as well as in gunshot wounds.

Since the introduction of antisepsis hospital gangrene has almost entirely disappeared.

Etiology of Hospital Gangrene.—The micro-organism of hospital gangrene has not as yet been discovered; but reasoning from the whole course of the disease, there can be no doubt that we have to deal with an infectious-wound disease caused by some one of the fungi. Rosenbach, in his last monograph on hospital gangrene, could give no information upon the exciting cause of the disease. The identity of hospital gangrene and diphtheria of the pharynx is still an open question, and many arguments *pro* and *con* have been advanced by different authors. W. Roser and Rosenbach have been the most outspoken against the identity of the two diseases. The pathological changes in hospital gangrene, like those in diphtheria of the pharynx, consist in an infarct of the infected wound, or in a coagulation necrosis, as it is called by Cohnheim and Weigert, in which are present great numbers of micrococci and bacteria of decomposition.

Clinical Cause of Hospital Gangrene.—Clinically the disease occurs in one of three forms: 1, The superficial croupous and diphtheritic; 2, the ulcerative diphtheritic, and, 3, the pulpy, the latter being the most malignant form. These different forms of the disease may run into each other, and clinically cannot always be sharply distinguished. The croupous or diphtheritic form of hospital gangrene is characterised by the development of hæmorrhagic foci accompanied by swelling, the foci subsequently breaking down and forming a foul, suppurating, jelly-like mass. By immediate treatment of the diphtheritic area with a concentrated chloride-of-zinc solution, or with the Paquelin thermo-cautery, the spread of this lowest grade of hospital gangrene can generally be arrested. The ulcerative form of the disease also begins with the development of hæmorrhagic spots having a grey or greyish-yellow colour, and at the outset is of limited extent; but in a relatively short space of time it spreads over the granulating surface and changes the latter into a grey or greyish-yellow mass, which subsequently breaks down into a gangrenous pulp. This gangrenous destruction of tissue may steadily advance inwards, and superficially may involve the skin adjoining the granulating surface by a spreading of the ulcerative process. The ulcerative form of hospital gangrene may change into the pulpy or most dangerous kind of wound diphtheria. In the pulpy form, according to König, there occurs, as a general rule, a rapid swelling of the tissues in consequence of the extensive hæmorrhages into the granulations, followed by putrefaction of the entire mass and the evolution of gases of decomposition. The borders of the wound are red and very painful. The swollen, grey, or greyish-red wound

looks, as König says, like a soft, decomposing spleen or mass of brain tissue.

The *course* of hospital gangrene depends, in general, upon whether the gangrene of the wound remains superficial or extends into the more deeply lying parts. Every form of hospital gangrene may destroy the skin and spread into the subjacent tissues, particularly if it is of the pulpy variety. The gangrenous changes advance very rapidly, and within twenty-four hours cause the wound to become double its original size, or even larger, but in other cases the changes take a much longer time.

The general symptoms correspond to the severity of the local disease. The fever may be continuous or remittent, with intercurrent chills. Very frequently the local disease begins with a rigour and a fever of 40° to 41° C. (104° to 105·8° F.).

Prognosis of Hospital Gangrene.—The prognosis of hospital gangrene depends upon the form of the gangrene and the nature of the treatment. The pulpy form of hospital gangrene has the most unfavourable prognosis of all. The strength of the patient and the conditions under which he has lived must be taken into account. The milder forms of hospital gangrene will often get well spontaneously, while the more severe forms will frequently cause death by general septic poisoning, unless the spread of the gangrenous process is combated sufficiently early and energetically by proper treatment. Recurrences of the disease take place not infrequently.

Treatment of Hospital Gangrene.—The treatment of hospital gangrene consists in the energetic use of the Paquelin thermo-cautery and of caustics, particularly nitric acid or chloride of zinc, to check the spread of the gangrene. Deeply placed gangrenous foci must be laid open with the knife, to permit the pus to escape and to enable the suppurating region to be energetically disinfected with a 1 to 1,000 solution of bichloride of mercury. Iodoform or naphthaline are excellent substances to apply in the dressings; or, if the gangrene is very extensive, antiseptic irrigation may be practised, as described on pages 178 and 179. If it becomes necessary to amputate a gangrenous limb, the operation should be performed with the strictest antiseptic precautions, after first energetically disinfecting the gangrenous focus, or burning it with the Paquelin thermo-cautery and covering it with an antiseptic dressing wet with bichloride.

Every patient with wound diphtheria should be isolated with the greatest possible care, as a protective measure for the other patients. Hospital gangrene, as has been said, does not occur at present with the antiseptic method of treating wounds; but in the time of war,

where the rules of antisepsis cannot always be strictly observed, hospital gangrene invariably makes its appearance.

§ 73. **Traumatic Tetanus** (*Trismus*).—Tetanus is an infectious-wound disease characterised by cramp-like contractions of the muscles of the lower jaw alone (trismus), or by contractions of certain other groups of muscles, or of the muscles of the whole body (tetanus). The cramps may affect at one time the muscles of the extremities, and at another the muscles of the anterior or posterior aspect of the trunk.

Etiology of Tetanus.—There used to be a great many theories concerning the nature and etiology of tetanus, but they did not account satisfactorily for its occurrence in the injured, and they are to be looked upon at present as untenable. Amongst them was the reflex theory, which supposed that tetanus was excited reflexly from irritation of the peripheral nerve trunks by an injury, a foreign body, or by the application of a ligature, or that the disease was due to changes in temperature, or to catching cold, etc. Verneuil, Roser and Heiberg were the first to affirm the infectious nature of tetanus and its causation by absorption of a poison from the wound. The recent investigations of Nicolaier, Brieger and Kitasato have proved beyond a doubt that tetanus is produced by a specific bacillus discovered by Nicolaier, and first obtained in pure cultures by Kitasato (Fig. 268).

Fig. 268.—Tetanus bacilli with spores from an agar culture (Kitasato). × 1000.

The injuries which may be followed by tetanus are of every description. Sometimes they are severe, and involve both soft parts and bones, such as compound fractures, and sometimes less severe, such as burns, frost-bites, or insignificant wounds of the skin or a granulating surface, or perhaps only a small punctured wound, etc. Tetanus has been known to come from a blister and the sting of a bee. We can easily understand, from the analogous origin of other infectious-wound diseases, particularly anthrax, how tetanus may follow the very slightest interruption of continuity in the skin. The disease is particularly apt to occur as a result of injuries to the hands or feet, in which are lodged foreign bodies, such as bits of earth or splinters of wood. Animals, such as horses, may often be the means of transmitting the tetanus bacillus to man. Occasionally the disease appears to break out after the lapse of a certain period of incubation, and consequently it is possible for tetanus to occur after the wound has entirely healed. The disease may become endemic under certain conditions—for instance, in hospitals where the rules of antisepsis and asepsis are not strictly observed. In

order to get a clear idea of the nature of tetanus, attempts were made to excite the disease experimentally in animals; but all attempts at inoculation failed until Kitasato and others finally succeeded quite recently, thus making it certain that tetanus is infectious in nature.

Experimental Inoculation of Tetanus upon Animals.—Carle and Rattone excised from a man who had died of tetanus the inflamed area of skin surrounding an acne pustule from which the disease had probably originated; an emulsion was prepared from the excised pustule and injected into the perineurium of the great sciatic nerve, the spinal cord, and back muscles of different rabbits. Of the twelve rabbits inoculated, eleven were seized with true tetanus and died within four days at the latest. Blood taken from the diseased animals and inoculated upon healthy animals did not excite the disease, but an emulsion made from material taken from the point at which the inoculation was made in the sciatic nerve produced fatal tetanus. Rosenbach and others succeeded in transmitting the disease from man to animals (guinea-pigs), and from the latter to other animals (guinea-pigs and rabbits).

Nicolaier's Earth Tetanus.—Nicolaier performed some very interesting experiments in Flügge's laboratory. While carefully studying the micro-organisms in surface soil, he was surprised to find that a disease similar to human tetanus was produced in a considerable number of cases (sixty-nine times in one hundred and forty experimental inoculations) by inoculating animals with earth taken from widely separated sources (Berlin, Wiesbaden, Leipsic and Göttingen). The inoculations with the earth were practised at the root of the tail in white and yellow mice, and beneath the skin in rabbits and guinea-pigs. In mice after the lapse of one and a half to two and a half days, or four to five days in rabbits, cramps occurred in the muscles in the neighbourhood of the region inoculated, and later the tetanus extended to the muscles of the other extremities and to those of the back and the nape of the neck. In rabbits, the muscles of the jaw became rigid in a state of tonic spasm, and death occurred after the lapse of one and a half to two days. Mice died twelve to twenty hours after the first symptoms of poisoning made their appearance. Dogs did not react at all when inoculated.

The post-mortem examination revealed, as in man, very little which was distinctive. Microscopically, in the slight amount of pus at the point of inoculation, micrococci were found, and particularly a peculiar bristle-shaped rod carrying spores. Nicolaier was not able to obtain pure cultures of this bacillus; he could not separate them from other bacilli, and consequently it was believed that tetanus was caused by a kind of symbiosis of different bacteria. The bacillus in question was found by itself in the subcutaneous tissues, but Nicolaier was almost never able to demonstrate microscopically the presence of the bacillus in the more deeply lying muscles and nerves, including the blood. Only in a few cases was he able to find the bacilli in the sheath of the sciatic nerve and in the spinal cord. When the earth was heated for an hour the inoculations were unsuccessful. Attempts at producing infection by pus taken from animals at the point where they were inoculated succeeded in sixty-four out of eighty-eight experiments, the disease running a more rapid course than when earth was employed. Inoculations with pieces of the infected tissues succeeded only fourteen times in

fifty-two cases. Nicolaier concluded, from his experiments, that tetanus was produced by the bacillus in question, which acted by producing a poison like strychnine, and not by simply increasing in numbers.

Socin has also excited true tetanus by making inoculations with garden earth. I saw one fatal case of tetanus following a compound fracture which had become befouled with earth. The patient came under my care after well-marked tetanus had developed.

Description of the Tetanus Bacillus.—Kitasato was the first to isolate Nicolaier's tetanus bacillus from the other bacteria found accompanying it; he cultivated it and excited tetanus in animals by inoculating them with the pure culture, and thus established the correctness of the suppositions which had existed about the disease. Kitasato placed in the necessary culture medium a small piece of tissue taken from the immediate neighbourhood of a suppurating wound in a man who had died of tetanus. The culture when placed in the incubator revealed a luxuriant growth of bacteria; but the kind which carried spores at one extremity developed the most rapidly, while the others only began to grow after the lapse of a certain length of time. Before these latter could develop Kitasato heated the mixed culture to a temperature of 80° C. and destroyed all the bacilli which had not taken on their permanent form, leaving only those which were capable of forming spores. From these he made a pure culture, which, when inoculated upon animals, established the fact that the bacillus containing spores in one of its extremities, and first discovered by Nicolaier, was actually the true bacillus of tetanus.

Pathogenesis of Tetanus.—The tetanus bacillus is a slender rod, somewhat longer though not as large in diameter as the bacillus of mouse septicæmia (Koch), and is found in the surface layers of ordinary earth, in decaying masonry, decomposing fluids, manure, or splinters of wood found in wounds, and in the pus from a wound upon a person who has died of tetanus. The rods sometimes form long filaments, upon which the divisions between the segments (bacilli) are almost indistinguishable. The bacilli, for the most part, collect in irregular groups. The tetanus bacillus possesses a recognisable though slight power of movement, and grows rather slowly, best at a temperature of 36° to 38° C. (96·8° to 100·4° F.), while below 16° C. no development takes place. It is obligate anaërobic—i. e., it grows only when atmospheric air is absent. In the presence of oxygen, the bacillus quickly died. In an atmosphere of pure hydrogen, small ray-like colonies develop slowly upon gelatine plates after the lapse of some days; they liquefy the nutritive medium with the evolution of gas, and present an appearance similar to the hay bacillus (a rather thick, solid centre, with radiating filaments). Stab cultures in a test tube containing a considerable amount of grape sugar gelatine, or in gelatine to which has been added 0·1 per cent. of indigo-sulphate of sodium, give a culture at the bottom of the tube having the appearance illustrated in Fig. 269. At the end of the first week it looks something like a fir-tree—i. e., numerous fine processes radiate outwards from the line of puncture, simulating the bacillus figurans. Subsequently the gelatine surrounding the colony is liquefied and there is an evolution of gas. In a test tube containing agar, to which has been added one to two per cent. of grape sugar or indigo-sulphate of sodium, the growth at the proper incubation temperature is more rapid and luxuriant, and after the first or second twenty-

four hours the culture causes an evolution of gas which has a characteristic unpleasant odour. In grape-sugar bouillon the growth of the culture is exceedingly vigorous, and is accompanied by the formation of a large amount of gas. In blood serum, at a temperature of 34° to 38° C., after the lapse of one to three days, small round cavities develop, which gradually coalesce.

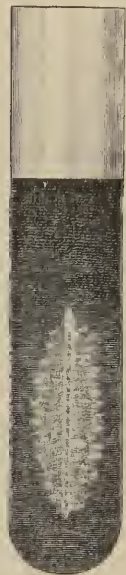

Fig. 269.—Tetanus culture. Stab culture in gelatine with indigo-sulphate of sodium. Seven days old.

Spore formation, at a temperature of 37° C., takes place in thirty hours, and occurs at one end of the bacillus, this portion of the cell swelling, and giving it the appearance of a drum-stick (Fig. 268). The spores have great vitality, and will remain alive when exposed in a moist state to a temperature of 80° C. for one hour, but are destroyed in five minutes when exposed to steam at a temperature of 100° C. Dried pus containing spores retains its virulence after the expiration of sixteen months. The tetanus bacillus is readily stained by the ordinary aniline dyes. Gram's method can also be employed.

If a small amount of a pure culture is inoculated upon mice, rats, guinea-pigs, or rabbits, the former two kinds of animals will manifest the first symptoms of the disease in twenty to twenty-four hours, the latter two in two to three days. If horses, sheep, or dogs are inoculated with the pure culture they will develop typical tetanus. The manifestations of the disease are at first local, and confined to the parts immediately adjoining the point of infection, from which they gradually spread, and the animal then dies in a short time. At the point of infection there is infiltration of the tissues and hyperæmia, but no suppuration, and sometimes it may be possible to demonstrate the presence of the bacilli; but they are never found in the different organs or in the blood. The latter fact is explainable on the ground that the bacilli form an extremely active poison, which spreads rapidly throughout the body. Brieger has obtained from tetanus cultures four toxines in a chemically pure state: tetanine $C_{13}H_{30}N_2O_4$, tetanotoxine $C_5H_{11}N$, spasmotoxine, and a toxine hydrochlorate. Very small amounts of these toxines produce in animals tetanic symptoms, but Weyl states that it is not typical tetanus.

The Tetanus Poison.—Weyl and Kitasato have also attempted to isolate the poisonous substances from pure cultures of the tetanus bacillus. They considered that Brieger worked with impure cultures. Weyl and Kitasato found a very poisonous substance closely allied to the albuminoid bodies, which produced, after the lapse of a certain period of incubation, the symptoms of tetanus, though they were not so typical as after an infection by the tetanus bacillus. Brieger, working with E. Fränkel, has also discovered the same body (tetanotoxalbumen). The toxine, isolated at an earlier date by Brieger, produced very acute tetanic symptoms, but not the typical picture of tetanus. The toxic substance obtained from different kinds of pure cultures of the tetanus bacillus varies—a fact which corresponds to what we know of other bacteriological investigations. By subcutaneous injection in mice, guinea-pigs, and rabbits, of the germ-free filtrate from bouillon cultures of the

tetanus bacillus, Kitasato obtained a typical tetanus which terminated fatally. Consequently intoxication by the tetanus bacillus seems to be caused by several different poisonous substances.

The poison exists in the serum of the blood, and after circulating through the system in this medium, it is excreted by the kidneys, which accounts for the particularly toxic powers of the latter organs. Bruschettini was able to excite tetanus in healthy animals by injecting into them subcutaneously the urine taken from animals suffering from this disease. Testana, on the other hand, was unable to demonstrate in the liver, spleen and kidneys the toxic substance of the tetanus bacilli.

Tetanus Immunity in Animals.—Great interest attaches to the experiments of Behring and Kitasato relating to the production in animals of immunity from tetanus. These authors succeeded in curing infected animals, and in so treating healthy ones that they were never afterwards affected by the tetanus bacillus. The blood and serum of rabbits which have been rendered immune from tetanus possess the power of destroying the tetanus poison. They are both prophylactic and curative. By transfusion of blood or serum remarkable therapeutic effects can be obtained—that is, infected animals can be cured, and healthy ones—mice, for example—can be rendered permanently immune. The artificially acquired immunity is transmitted from the animal to the fœtus *in utero*, and persists in the young for some time after birth. Tizzoni and Cattani have made white mice immune by the serum of the blood taken from frogs and pigeons which are unsusceptible to tetanus; but Kitasato, experimenting with the blood of chickens, has contested their assertions. Kitasato has rendered rabbits immune from tetanus by injections of iodoform. Tizzoni and Cattani state that rabbits from which the spleen has been removed cannot be made immune. The future must decide whether the facts established about the action of blood serum in curing animals affected with tetanus is of therapeutic value for man in a similar condition. Vaillard's experiments seem to make the hope of success in this line rather doubtful. Tizzoni, Cattani and others have prepared curative serum (antitoxine) from animals which have been made immune from the disease, and have recommended it for use in man. As yet no definite conclusion has been reached upon the success which may be obtained by the subcutaneous injection of this remedy.

Sormani gave pure cultures of tetanus bacilli and the flesh of animals dying of tetanus to herbivora and carnivora, and both classes of animals remained healthy; but in the fæces of these animals, particularly the herbivora, he found an active tetanus poison which was capable of communicating the disease.

Disinfection of Objects Infected with the Tetanus Poison.—The disinfection of all objects infected with the tetanus poison is best carried out by subjecting them to the action of steam at a temperature of 100° C. to 130° C. (212° to 266° F.), or by boiling them in a one-per-cent. aqueous solution of soda. For the disinfection of hospital wards, rooms, etc., Bombicci recommends nascent chlorine, while a ten-per-cent. solution of chloride of lime can be used for stone walls, or, better, a mixture of ten parts of chloride of lime, twenty-five parts of quicklime, and one hundred of water. Fluid coal tar is excellent for wooden walls. Tizzoni and Cattani recommend a mixture of

one per cent. bichloride of mercury, five per cent. carbolic acid, and five tenths per cent. hydrochloric acid for disinfecting the hands of the surgeon.

Tetany after Extirpation of Goitre.—It is well known that tetany may follow total extirpation of the thyroid gland. It is characterised by a peculiar condition of irritation of the anterior horns of the grey matter of the spinal cord. The tonic spasm, which chiefly affects the hands and feet, used to be thought to be due either to irritation of the peripheral sympathetic nerves, caused, for instance, by ligation of a great number of vessels, or to the division of the numerous nerves of the thyroid gland. Horsley and others state that tetany only occurs after total extirpation of the thyroid, and never after a partial extirpation or removal of half the gland. But Eiselsberg produced tetany in cats by removing four fifths of the thyroid ; the disease, however, was not always fatal, while the tetany following total extirpation was invariably so. Consequently it follows that the thyroid gland is functionally a very important organ, and its total removal will cause death. Horsley, Wagner and Eiselsberg consider that the function of the thyroid is to render mucoid substances innocuous. After its total extirpation there results an accumulation of mucin in the tissues (myxœdema), and death is caused by mucin poisoning with tetanic symptoms. Herbivora, such as rabbits, stand total extirpation of the thyroid gland better than carnivora, such as dogs or foxes.

The Clinical Course of Tetanus.—The clinical picture presented by tetanus in man is briefly as follows: About the third or fourth day after infection, or still later, it is noticed that the patient cannot open his mouth properly, and complains of pain in the muscles of mastication. At the same time there is usually a high fever, though in the less acute cases the fever may be absent. As a result of the cramp-like contraction of the facial muscles, the countenance assumes a peculiar rigidity. There soon follows a certain amount of stiffness of the neck, with tetanic spasms lasting a few or several minutes, and affecting at one time the trunk and at another the extremities; they are very painful, and are excited by the slightest external irritation—for example, by touching the patient, by a draught of air, a noise, etc. Many of the muscles become firmly and permanently contracted. Tetanus does not always begin with a cramp-like contraction of the muscles of mastication (trismus). If the patient is carefully watched, it may be noticed that there is at first a peculiar stiffness and contraction of the muscles in the neighbourhood of the injury or point of inoculation, occurring perhaps in the upper or lower extremity, and subsequently tetanus will develop in the other groups of muscles. These facts were observed by Nicolaier and Kitasato in their experiments upon animals, which have already been described. The fever in tetanus is usually high, the rise in temperature not infrequently reaching 41° to 42° C. (105·8° to 107·6° F.), or even 43° to 44° C. (109·4° to 111·2° F.), while after death there is some-

times a further rise to about 45° C. (113° F.). This excessive increase in body heat is essentially the result of muscular contraction, as was also proved by Leyden's experiment, in which, within two hours, the temperature of a dog was made to rise from 39·6° C. (103·2° F.) to 44.8° C. (112·6° F.), simply from the frequently repeated muscular contraction caused by powerful electrical stimulation of the spinal cord. The patients usually retain perfect consciousness, and are bathed in sweat. The urine contains albumen, probably as a result of the tetanic contraction of the renal arteries. There are also cases which may run a rapidly fatal course and yet be unaccompanied by fever. In these there is an extensive muscular rigidity, particularly about the head and trunk, the patients hold themselves perfectly stiff, and there are none of the above-described muscular contractions alternating with a momentary abatement of the rigidity.

Acute tetanus is usually fatal. Death may occur within twenty-four hours from the beginning of the disease, or after the lapse of four to five days. There is also a subacute or chronic form of trismus or tetanus which ordinarily is not accompanied by fever. Sometimes the tetanus remains limited to the muscles in the neighbourhood of the injury, affecting perhaps the arm alone, or the injured leg, or the muscles of the head.

Head Tetanus.—Rose, Bernhardt and Güterbock state that the so-called head tetanus occurs after injuries in the region of the distribution of one of the twelve cranial nerves. It is distinguished particularly by tetanic contractions of the muscles of mastication—by trismus, as it is called—which is combined with facial paralysis and spasm of the muscles of the pharynx, as in hydrophobia, and hence is sometimes given the name of tetanus hydrophobicus. The paralysis of the facial nerve, according to Rose's view, is caused by compression of the swollen nerve in the aqueductus Fallopii, but this cannot always be demonstrated in the post-mortem examination. Brunner has excited head tetanus in guinea-pigs and rabbits by inoculating into the heads of these animals a pure culture of the bacillus; and he found that there was no paralysis of the affected half of the face, but that the asymmetry of the sides of the face, apparently due to facial paralysis, was really due to tetanic contracture.

When inoculation was practised in the median line, both halves of the face became tetanised. If the facial nerve was divided upon the inoculated or diseased side of the head, real paralysis appeared for the first time, and the rigidly contracted muscles became relaxed. Brunner thinks that the supposed facial paralysis in head tetanus, in man, is probably an error in observation, though P. Klemm, basing his opinion

upon an analysis of thirty-eight published cases, has contested this conclusion. Head tetanus is not always fatal, particularly chronic cases, which Klemm's statistics show may last from four to twelve weeks, and are much more apt to terminate favourably than the acute form of the disease. Güterbock and Bernhardt collected fourteen cases with four recoveries. Klemm had one case of chronic tetanus hydrophobicus, and collected the reports of twenty-four others, seven of which recovered, six of these being chronic.

Pathology of Tetanus.—The *anatomical changes* in *tetanus* are slight. The microscopical examination of the spinal cord and the neighbouring peripheral nerves shows an extensive proliferation of the cells. Monastyrski found half-moon-shaped extravasations of blood in the interstitial connective tissue of the spinal cord and peripheral nerves, and a granular infiltration of the nerve cells.

Prognosis of Tetanus.—The prognosis of tetanus, as may be gathered from what has been said above, is for the most part unfavourable. Acute tetanus generally terminates fatally, while the subacute and the rare chronic forms of the disease have a more favourable prognosis. In those cases in which the tetanus is confined to the muscles of one limb, or to the head (tetanus hydrophobicus), the disease does not always terminate fatally.

Treatment of Tetanus.—Treatment in acute tetanus has little effect. In the first place, the injury or wound should always receive proper surgical treatment according to antiseptic rules. It is very important that every wound which has become soiled with earth, or similar substances, should be thoroughly cleaned and disinfected as soon as possible. Tizzoni and Cattani recommend, for the disinfection of wounds in which there is fear of the development of tetanus, a one-per-cent. solution of nitrate of silver, which destroys the bacilli and the spores very rapidly and certainly—in one minute. If tetanus already exists when the case comes under observation, we are, as a general thing, powerless to hold it in check, and almost all the patients die after a very short time. Very rarely, and then only when the case is seen immediately after the reception of the injury, can tetanus be checked by burning the wound with the thermo-cautery. Recovery may often be obtained by amputating the injured limb, though even this is sometimes unsuccessful. Especially in tetanus following injuries of the extremities, attempts have been made to arrest the disease by exposing and stretching the principal nerve trunks—the sciatic, for instance—which supply the injured portion of the body, and Verneuil, Kocher and others have reported cures by this treatment. The good obtained from nerve-stretching in infectious tetanus is certainly open to doubt (§ 97).

The remainder of the treatment for tetanus is purely symptomatic. Subcutaneous injections of morphine are often used, accompanied by the administration of chloral hydrate (three to five grammes *pro die*) by the rectum, or large doses of chloral hydrate or bromide of potassium may be given internally, two grammes of chloral hydrate being alternated with the same amount of bromide of potassium every two hours. Kane states that, of two hundred and twenty-eight cases treated with chloral hydrate, one hundred and thirty-four recovered and ninety-four died. Of ninety-three treated with chloral hydrate in combination with other remedies, thirty-three died. The most efficient means for quieting a patient during a paroxysm is to administer chloroform by inhalation; but after the cessation of the narcosis the muscular spasm immediately recurs. Curare, the Indian arrow poison, which has the power of paralysing voluntary muscles, is an exceedingly valuable remedy, though very inconstant in its effects on account of its variable chemical composition. The success of the curare treatment has not, however, been very encouraging. Its concentration varies within wide limits. Curare can be injected in the dose of about 0·015 to 0·05 grammes every quarter to half to one hour. Karg has curarised patients (by subcutaneous injection) till respiration became paralysed, after previously performing a prophylactic tracheotomy for facilitating artificial respiration; but all the cases treated in this way terminated fatally. It is a better plan to combine the administration of narcotics with injections of curare. Bacelli has obtained satisfactory results by injections of carbolic acid (0·01 gramme every hour). Sormani recommends iodoform. According to the latter's experiments, the tetanus poison is neutralised by iodoform, or by the iodine derived from it; and by treating the wound with iodoform during the period of its incubation tetanus can be prevented. He states that mice inoculated simply with earth died of tetanus in less than three days; but if the earth used in the inoculations was first mixed with iodoform the animals remained unaffected by the disease. Pure cultures are not changed when iodoform is added to them, but are killed in one minute by the addition of a one-per-cent. solution of nitrate of silver (Tizzoni, Cattani). Sormani also recommends iodol and a two-per-cent. acid solution of bichloride of mercury, or chloral with camphor. The further treatment of the disease consists in careful isolation of the patient, and in keeping away from him every sort of external irritation or disturbance, particularly during the stage when the muscular spasms are a prominent symptom.

De Renzi has succeeded in curing four out of a total of five cases of tetanus by securing to the patient absolute rest, which is the very

best curative agent at our disposal. De Renzi places the patient with tetanus—the ears having been plugged—in a room which is completely isolated, absolutely quiet, and without windows. All the necessary manipulations in the care of the patient are performed, as far as possible, in the dark. The nourishment is entirely fluid. When the pain is severe De Renzi gives belladonna and ergot internally.

Value of "Curative Serum" (*Antitoxine*).—It has been mentioned before that Behring, Tizzoni, and Cattani have prepared and recommended a curative serum (antitoxine) for treating tetanus in man. It is made from the blood serum of dogs, less often of rabbits which have been rendered immune from the disease, and when injected subcutaneously in man is said to have cured a number of cases of tetanus; but as yet it is impossible to come to any definite conclusion upon the therapeutic value of this serum.

§ 74. **Septicæmia.**—The term *septicæmia* is given to a poisoning of the body (intoxication) which, as a rule, rapidly terminates in death, and is not characterised by the formation of such metastatic suppurative processes as occur in the disease called pyæmia (pus poisoning), which is closely related to it. Septicæmia is usually found in conjunction with putrefactive (gangrenous) changes in a wound or inflammatory focus, though it may sometimes have an intestinal or pulmonary origin. It is often perfectly impossible to make a sharp distinction between pyæmia and sepsis, as the two diseases are frequently found in combination, both clinically and anatomically, and hence the term *septicopyæmia.*

Cryptogenetic Septicæmia.—Oftentimes the point at which the infection gains access to the system cannot be found, and we then speak of a cryptogenetic septicæmia.

Etiology of Septicæmia in Man.—Virchow, Billroth and others produced septicæmia by injecting decomposing substances into the vascular system and tissues of animals, and the discoveries in fermentation and decomposition which were made about the same time helped to shed light upon the importance of lower organisms in the production of sepsis. Then Panum demonstrated that analogous septic diseases could be excited by using decomposing fluids which had been boiled after the fungi existing in them were removed. This theory of the origin of septicæmia, partly from bacteria and partly from fluids free of bacteria, is now being still further elaborated, so that at present we distinguish two principal forms of septicæmia, one caused by fungi and the other by soluble chemical poisons. The septicæmia due to the presence of bacteria is an infectious disease capable of transmission to other animals; in other words, the blood of animals having this kind of sepsis will produce the same disease when inoculated into healthy animals. The virulence of the blood increases each time it is taken from an animal having the disease and inoculated into a healthy one—that is, its virulence

bears a direct proportion to the frequency of its transmission from one animal to another.

In the second form of septicæmia, the blood contains dissolved in it chemical poisons or gases, the poisonous products of the metabolism of the fungi, and it is not infectious any more than the blood of an individual suffering from strychnine or prussic-acid poisoning.

Between the two forms of septicæmia, the one due to toxines and the other to bacteria, there are numerous transition and combined forms ; in other words, bacteria of every description are sometimes found in the blood of those suffering from poisoning by the chemical products of bacterial metabolism.

The changes which take place in decomposition are of great importance for an understanding of the etiology of septicæmia. It has been mentioned that in the decomposition excited in albuminous bodies by bacteria, various substances are formed, the chief of which are peptones and similar bodies, nitrogenous bases (leucine, tyrosine, amine), organic fatty acids, aromatic products, colouring matters, and particularly poisonous toxalbumens, and certain alkaloids to which have been given the name of cadaver alkaloids or ptomaines. The latter possess intensely poisonous properties. It had long been known that toxic bodies were present in the products of decomposition, as Panum, in 1863, had isolated from putrefying substances his putrid poison. Bergmann and Schmiedeberg obtained a crystalline body, sepsine, Billroth discovered another, etc. Selmi was the first to recognise the nature of these bodies, and he gave them the name of cadaver alkaloids or ptomaines. Brieger and others have obtained several ptomaines in a pure state, such as collidine, peptoxine, neurine, neuridine, choline, etc., and have investigated their action upon animals.

Paterno, Spica and others found that ptomaines are also a product of normal metabolism, though, of course, they are formed in small amounts. Bergmann and Angerer have proved that febrile diseases similar to septicæmia can be produced by non-bacterial poisons such as ferments. In a case of septic (putrefactive) intoxication occurring without the presence of micro-organisms in the blood, there will somewhere be found a focus of suppuration or some decomposing pus or blood, the decomposition being due to micro-organisms, particularly the various kinds of bacilli. If the focus of suppuration is removed early enough recovery may take place. In these foci of suppuration or gangrene there will be not only the bacteria of decomposition, but many others, such as pyogenic staphylococci, streptococci, and different bacilli.

Septicæmia in man is caused sometimes by bacilli and sometimes by cocci (streptococcus pyogenes, streptococcus septicus Flügge, staphylococcus aureus). Ogston and Rosenbach identified the streptococcus pyogenes as the cause of the septicæmia in a case of progressive gangrenous phlegmon which produced fatal sepsis. In the septicæmia following progressive gangrenous emphysema, Rosenbach and others found the very bacillus which Koch proved to be the cause of malignant œdema—a disease running a rapidly fatal course in mice, guinea-pigs, and rabbits.

These œdema bacilli (Fig. 270), which Pasteur formerly designated as vibrions septiques, are morphologically similar to the anthrax bacilli (Figs.

264, 265). It is interesting to note that the symptomatic anthrax occurring endemically in cattle is produced by similar bacilli, and that their multiplication in the subcutaneous cellular tissue causes inflammatory swelling with the evolution of gas. Furthermore, in hæmorrhagic septicæmia many kinds of bacilli have been found. Lubarsch observed a case of septic pneumonia in a newborn child which died two days after birth.

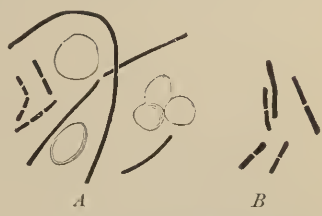

Fig. 270.—Bacillus of malignant œdema (vibrion septique Pasteur): *A*, from the spleen of a guinea-pig; *B*, from the lung of a mouse (Koch).

Experimental Septicæmia in Animals.—Thanks to Robert Koch, we possess a more accurate knowledge of human septicæmia on account of this investigator's experiments upon animals. There is a toxic septicæmia (septic intoxication), and a septicæmia which is bacterial in its nature (transmissible septic infection). Toxic septicæmia occurs after the injection of large amounts of decomposing substances into the subcutaneous cellular tissues. Immediately, or soon after the injection, there ensue restlessness, weakness, cramps, often vomiting, finally paralysis, and not infrequently death follows in a few hours from paralysis of respiration. No bacteria are found in the blood or internal organs. If decomposing fluids, with the bacteria of decomposition, are kept for twenty-four hours in the incubator at a temperature of 40° to 41° C. (104° to 105·8° F.) and then used for injection, the poisonous effects are very pronounced; but if the fluid is treated in the same way for forty-eight hours, no effects follow its injection.

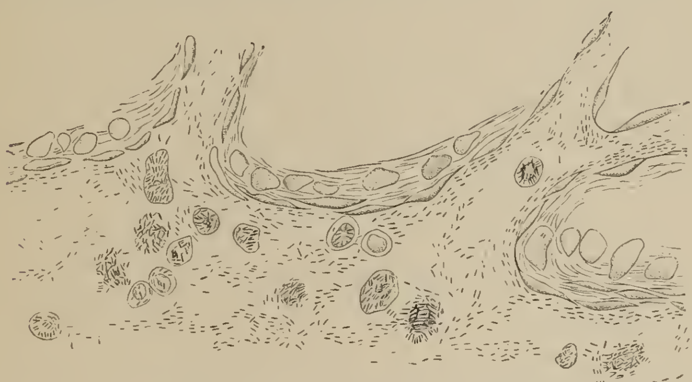

Fig. 271.—Bacilli of septicæmia in a vein of the diaphragm, taken from a septicæmic mouse. White blood-corpuscles, some containing bacilli, and some changed into masses of bacilli. × 700 (Koch).

In the bacterial septicæmic infection great numbers of bacteria will be found in both the blood and the tissues. Koch showed that there were two kinds of bacterial septicæmia: the septicæmia of mice and the septicæmia of rabbits, both of which are caused by bacilli. The bacilli of mouse septicæmia are very fine rods (Figs. 271, 273), like the bacilli of swine erysipelas; whilst the bacilli of rabbit septicæmia, recently described by Gaffky, are identical with or closely related to the bacteria of chicken cholera, the bacilli

of swine fever, and the bacilli of duck cholera. Hueppe proposes to call these micro-organisms the bacteria of septicæmia hæmorrhagica. There are, of course, poisonous metabolic products developed in these bacterial septicæmiæ, and Hoffa has isolated from the animals suffering from rabbit septicæmia a poisonous base, methylguanidin ($C_2H_7N_3$), probably produced by the oxidation of creatin. Animals are also afflicted with cocci-septicæmiæ. To this class belongs Fränkel's coccus of sputum septicæmia, which, when the saliva from the human mouth is injected into rabbits, is the exciting cause in these animals of septicæmia. This same coccus is in all probability the excitant of croupous pneumonia in man. The streptococcus septicus and a coccus found by Nicolaier in foul earth are precisely similar to the streptococcus pyogenes, as is also the micrococcus tetragonus. Severe septicæmia is occasionally transmitted from parrots to man. Lepetit found as its cause a small coccus which he obtained from the blood and made pure cultures of. He found the staphylococcus aureus and citreus in the lungs.

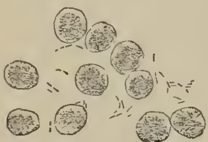

Fig. 272.—Blood from a septicæmic mouse, dried on a cover glass, stained with methyl violet, and laid in Canada balsam. Red blood-corpuscles and small bacilli. × 700 (Koch).

Fig. 273.—White blood-corpuscles from a vein in the diaphragm of a septicæmic mouse. This shows how the corpuscles become gradually changed into a mass of bacilli. × 700 (Koch).

Bacteria of Decomposition.—Hauser has taught us the morphology and biology of three kinds of bacteria causing decomposition, and called by him proteus vulgaris, proteus mirabilis, and proteus Zenkeri. From small rods similar to Cohn's bacterium termo there develop in proper nutritive media longer rods and screw-shaped filaments, which, after exhausting the nutritive medium, change into short rods and spherules, which are probably spores. These three kinds of bacteria, isolated from decomposing substances, are capable of exciting decomposition, while the filtrate freed from bacteria did not have this power (saprogenic). The investigations about their pathogenic properties and their relationship to septicæmia revealed the fact that these three bacteria evolved, by exciting decomposition of animal tissue, a violent chemical poison, which, when introduced in very small amounts into the blood and lymphatic vessels of small animals, caused the death of the latter with every symptom of putrid intoxication. These bacteria, which are saprophytic, are not themselves pathogenic—that is, they are not capable of developing within the living body. Rosenbach has cultivated three kinds of saprogenic bacteria, two of which are toxic.

Ferment Intoxication and Septicæmia.—Semmer, Rossbach and Rosenberger have made experiments which show that after the injection of ferments or sterilised septic blood the animals thus treated will die of sepsis, from the development of bacteria in the blood. If these experiments are free from error, it seems to prove that the properties of the blood are so changed by the injection of the above-named substances that it is rendered possible for bacteria to develop in it—a thing which would be impossible if normal conditions existed in the blood and tissues. But there is some reason

to doubt that the substances injected in these experiments were actually free from all contamination by bacteria. Bergmann and Angerer have made some interesting discoveries as to the relationship of ferment intoxication to septicæmia. It is well known that Birk and others, by transfusing blood containing ferment, or by injecting fibrin ferment into the blood, obtained in the animals experimented upon, both during life and after death, the same phenomena which occur after the introduction of fluids which are decomposing or rendered foul by bacterial vegetation. The changes consist essentially in a more or less extensive disintegration of the white blood-corpuscles, with a secondary formation of fibrin in the capillaries, the large pulmonary vessels, and in the heart. Bergmann and Angerer excited the same changes by injecting large doses of sterilised, transparent, aqueous solutions of pepsin and pancreatin. The severe ferment intoxications run a rapidly fatal course, presenting the picture of intoxication by decomposing substances. The pure ferment consequently acts in a manner similar to the pathogenic bacteria—that is, mainly by destroying the white blood-corpuscles. These investigators were unable to confirm the above-mentioned statements of Rosenberger and Rossbach, that bacteria can develop as a result of the presence of sterilised ferment solutions in the blood.

Occurrence of Septicæmia.—Septicæmia in man, since the antiseptic method of treating wounds has come into general use, is of much less frequent occurrence than was formerly the case. Antisepsis, carefully carried out in every operation and in the subsequent treatment of every wound, is the best guarantee against the occurrence of septicæmia. If septicæmia should make its appearance after an operation upon healthy tissue, it is a proof that there has somewhere been a transgression of the rules of asepsis. The septic poison, the micro-organisms, may gain access to the wound in many different ways—for instance, at the time the injury was received, or by infected instruments, unclean fingers, etc.

Pathological Changes in Septicæmia.—The pathological changes in septicæmia consist, in the first place, in the local changes at the point of infection and the surrounding parts, which will be more minutely described when we come to the symptomatology. The most constant change is found in the blood after death. It is dark-coloured, like tar, prone to rapid decomposition, and not infrequently has an acid reaction (carbonate of ammonia). The above-mentioned micro-organisms will be found in the vessels and blood, and in the tissues of the different organs, though in cases of pure intoxication the micro-organisms will not have a general distribution throughout the body, but will be present only in the focus of infection. The disintegration of the white and, to a less extent, of the red blood-corpuscles, brought about by the micro-organisms or by the products of their metabolism, is characteristic. The bacteria are present in the white blood-corpuscles, in which they are scattered through the system, and finally change the leucocytes

into masses of bacteria (Figs. 271, 273). As a result of the disintegration of the white blood-corpuscles, the blood possesses an increased power of coagulation. In consequence of the changes in the composition of the blood and the alterations in the walls of the vessels, allowing their contents to escape through them, there arises a tendency to small and large hæmorrhages in the gastro-intestinal tract, in the mesentery and omentum, in the spleen, endocardium, pleura, kidneys, bladder, and, in short, in all the different organs. The changes occurring in the heart and lungs are not constant, there being sometimes a general pleurisy, and sometimes symptoms of pericarditis. In the intestinal canal there is frequently an extensive enteritis, taking the form of a catarrhal swelling with ecchymoses, and the formation of ulcers, as in a dysenteric inflammation. The spleen is almost always large and soft, and the liver is likewise somewhat enlarged, congested, and friable. The kidneys are increased in size, the parenchyma is in the stage of cloudy swelling, and there is a catarrhal change in the uriniferous tubules. The above-mentioned micro-organisms will be found most abundantly in the kidneys, and chiefly in the capillaries of the glomeruli and in the afferent vessels. The changes in the internal organs are sometimes very slight. Diffuse metastatic inflammations, embolic infarcts and foul abscesses also occur in septicæmia, especially when the latter is combined with pyæmia (pyo-septicæmia); but they are by no means so frequent or so characteristic of septicæmia as are the metastatic suppurations for pyæmia.

The Clinical Course of Septicæmia.—The *symptoms* of septicæmia are, for the most part, characterised by the presence of a high and generally continuous fever, and by a number of inflammatory processes. The two different forms of septicæmia—distinguished in respect to their etiology, the putrid or septic intoxication due to the products of bacterial metabolism, and that due to the presence of bacteria—cannot clinically be sharply differentiated, and in man, as we have stated before, they not infrequently occur in combination. It is impossible to describe the symptoms of septicæmia so as to include all its forms.

The wounds which are capable of giving rise to septicæmia may be fresh or granulating. Every wound, no matter how small, can be the starting-point for septic infection. It was formerly believed, from Billroth's experiments, that healthy granulations were impermeable for decomposing fluids and for micro-organisms, but Maas and Hack proved that this view was not correct. The local manifestations at the point of the injury vary greatly, and they may, in fact, be entirely absent, as in the cases of septicæmia which run a very acute course. These are characterised by a rapid febrile intoxication of the whole

system, which occurs before there are any local symptoms in the wound. In the worst cases there is a gradual clouding of the mind, followed by stupor and death, within the first two or three days.

The febrile movement is not characteristic in septicæmia; in fact, there are forms of the disease which run their course without

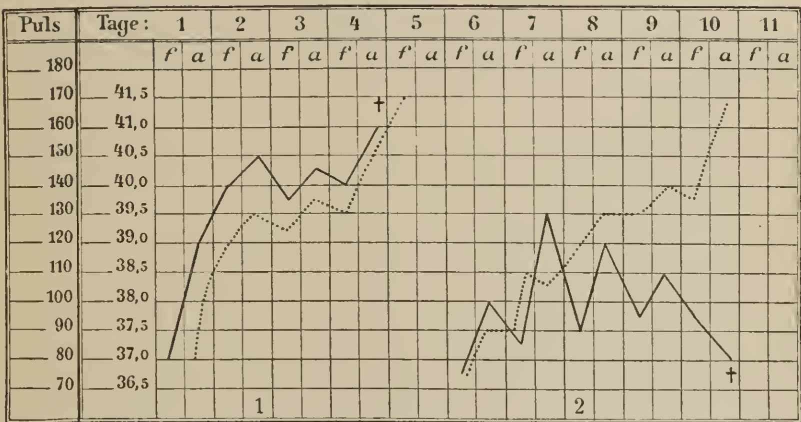

Fig. 274.—Temperature curves in septicæmia: 1, temperature curve in septicæmia, with high fever; death with a temperature of 41° C. (105.6 F.), and pulse of 170 on the 3rd day after the operation (Laparatomy); 2, temperature curve in septicæmia with a slight rise of temperature; death on the 4th day after the injury (gun-shot wound), preceded by a subnormal sinking temperature and very rapid pulse.

any fever at all. On the other hand, the frequency of the pulse is always noticeably increased (Fig. 274). If the ordinary wound-fever, occurring after open injuries from the absorption of the products of decomposition, is looked upon as a septic intoxication, it must be admitted that we frequently meet with transient abortive forms of septic intoxication, which are marked by a moderate rise of temperature to about 39° C. (102·2° F.), and terminate favourably in a few days without giving rise to any appreciable complication in the wound or in the internal organs. This simple septic fever is of very common occurrence, while it is relatively seldom that we meet with the above-mentioned severe cases of septic intoxication which run a rapidly fatal course. In discussing fever in general, we learned that the latter may be caused by the absorption of substances which were not decomposed, such as fibrin ferment, etc.—a condition which Volkmann and Genzmer have designated as wound-fever. Consequently our present knowledge of the etiology of fever makes it impermissible to look upon every rise in temperature in those who have been injured as a septic fever.

All cases of general sepsis in which the inflammation is plainly spreading from the point of infection have, in general, an unfavourable

prognosis. The severity of the constitutional symptoms and the extent of the local inflammatory process vary here, too, very much, the latter showing all the steps from a mild lymphangitis to a violent septic phlegmon or an acute septic gangrene. In this class belong the cases of septic infection which arise from very slight injuries, such as are not uncommon on the fingers of surgeons after operations upon abscesses, decomposing tissue, etc., from infection by putrefying matter. After twelve to twenty-four hours there is a chill, and the temperature rapidly rises to 39·5° C. (103·1° F.) or 40° C. (104° F.) and higher, the small wound on the finger becomes painful and is inflamed, the epitrochlear and axillary glands swell, and red streaks appear on the arm (septic lymphangitis). By the next day, if proper treatment is employed, the septic infection may have run its course, or recovery may take place with the formation of pus at the point where the injury was received, and with the development of circumscribed abscesses in the epitrochlear and axillary glands, or death may follow from general septic poisoning. In other instances, the septic inflammation starting from the wound is severe, and leads to an extensive, rapidly spreading cellulitis, which is accompanied by high fever, as described on page 336. Rarely, and then particularly after severe traumatisms, such as a "run-over" accident, a rapidly advancing, putrefactive inflammation will develop with the evolution of gas in the tissues, usually terminating in death within the first forty-eight hours. The gangrene of the tissues in such cases may in the first place be caused by the injury alone, and then, in addition to the local traumatic gangrene, there is added a rapidly extending decomposition, due to the entrance of the germs of decomposition, which may spread, and involve the entire extremity. Sometimes this traumatic origin of the gangrene due to contusion of the tissues can be excluded, and yet there will be a rapidly spreading gangrene, with decomposition and the evolution of gas. This is sometimes the case in snake bites. The acute purulent œdema of Pirogoff and the *gangrène foudroyante* of Maisonneuve belong to those worst forms of septic inflammation. The affected extremity is usually excessively swollen, partly from œdema and partly from the gases produced by decomposition. At the same time there is given off a foul odour, and a crackling emphysema of the skin radiates in all directions from the wound. The muscles become changed into a reddish brown mass full of bubbles of gas. Coma and death follow in a few days, usually preceded by an increase in the œdema. This progressive gangrenous emphysema (gangrène gazeuse), which, by the way, is of very infrequent occurrence since the introduction of antiseptic methods, is caused by bacilli similar to those which Koch identified as the cause of malignant œdema in

mice, guinea-pigs, and rabbits. Progressive gangrenous emphysema occurs in conjunction with compound fractures, or any deep wound into which earth or some other material containing the œdema bacilli has penetrated.

The other symptoms of septicæmia referable to the internal organs are caused by the general septic infection. Usually the spleen is plainly enlarged, and very often the liver also. Not infrequently there is jaundice, generally of a hæmatogenous nature, as a result of the disintegration of the red blood-corpuscles caused by the micro-organisms or their products. There are usually gastro-intestinal disturbances, which in the severer forms of septicæmia give rise to a diarrhœa which is sometimes fæculent, sometimes mucous, or even bloody-diphtheritic in character.

The urine ordinarily contains albumen. The diffuse inflammations of the pleura, the pericardium and endocardium give rise to marked symptoms only in exceptional cases. There are not infrequently exanthematous eruptions of the skin, which take the form of blebs or pustules, or resemble urticaria, measles, or scarlet fever. Veins and arteries may be opened by decomposing abscesses, leading to dangerous hæmorrhages.

Prognosis of Septicæmia.—The prognosis of septicæmia is, in the pronounced cases of microbe-septicæmia, for the most part unfavourable. The cases of intoxication by decomposing substances in which, by proper treatment, we can remove from the body the focus of infection, have relatively the best prognosis. After this procedure has been accomplished the absorption of the products of bacterial metabolism ceases, and with it also the poisoning. But it is important to bear in mind that a patient may apparently recover from septicæmia by encapsulation of the infectious matter, and yet, after the lapse of a longer or shorter time, it may again enter the circulation, being set free, perhaps, by some slight trauma or by a violent muscular contraction, and cause the death of the patient. The experiments of Grawitz, Behring and others make it seem probable that the powers of the organism for withstanding septic intoxication are weakened principally by the extensive disintegration of the red blood-corpuscles brought about by the toxic substances.

Diagnosis of Septicæmia.—In the diagnosis of septicæmia, the behaviour of the original wound or injury and the inflammatory manifestations in it, the presence of decomposition of the blood, wound secretion, or pus, and the presence of fever, and particularly the increased frequency of the pulse, are all important. In those cases of septicæmia in which, without noticeable local inflammatory symptoms,

there occurs within a few hours of the reception of the injury a severe fever, the diagnosis can usually be cleared up by getting an exact history of the injury. A small and very rapid pulse is exceedingly important in making the diagnosis of septicæmia. The greatest diagnostic difficulties will be met with in those cases in which no source of infection can be found, in the so-called cryptogenic septicæmia or septicopyæmia, the origin of which can only be ascertained during the course of the disease or at the post-mortem examination. Wagner has published a very instructive account of a number of cases of this kind.

The So-called Surgical Scarlatina.—In speaking of the symptomatology of pyæmia and septicæmia, we mentioned the occasional occurrence of exanthematous eruptions in the skin, particularly those which resemble the eruptions of measles and scarlet fever. Surgical scarlet fever, as it is called, has been described by Thomas, Riedinger, and Hoffa. It is sometimes a purely vasomotor disturbance. In addition to this eruption of septicæmia, pyæmia, and erysipelas, due to vasomotor disturbance, there is also a real scarlatina which occurs, particularly in children, after operations and the reception of wounds. In such cases the poison of scarlet fever passes directly from the wound into the general circulation. E. Koch collected twenty-six cases of true scarlatina following operations and the reception of wounds among the patients of the children's hospital at Basel, and he states that the period of incubation in this wound scarlet fever is shorter than in the usual non-surgical form.

Treatment of Septicæmia.—The treatment of septicæmia consists, in the first place, in treating any injury which may be present with the greatest surgical care. Every infectious-wound disease, and consequently septicæmia, can be avoided by antisepsis or asepsis if strictly carried out. If fever follows an injury or an operation, the wound should be most carefully examined, and any retention of decomposing blood, of the wound secretion, or of pus, should be immediately remedied by incision and drainage, and this should be followed by disinfection with a 1 to 1,000 solution of bichloride of mercury or a three- to five-per-cent. solution of carbolic acid. The special treatment for local inflammation and suppuration is described in §§ 67–72. In septicæmia which is the result of a severe septic phlegmon with extensive gangrene, it may not infrequently be necessary to sacrifice an entire limb, by amputation or disarticulation, to save the life of the patient. But it should be borne in mind that in an extensive septic cellulitis, numerous free incisions, followed by thorough disinfection of the infective focus thus freely exposed, may be sufficient to answer every purpose; though, on the other hand, amputation should not be too long delayed, as the patient may even after that die of septicæmia. The rest of the treatment is wholly symptomatic; there is no effective

remedy for counteracting septic constitutional infection. The treatment of the fever is conducted on the rules laid down in § 62. If the skin of an infected patient is dry, Billroth recommends that the excretion of the poisonous substances be hastened by exciting pronounced diaphoresis, either by placing the patient in a warm bath for an hour, or by wrapping him up warm in blankets, or by administering large quantities of a hot drink, etc. As a matter of fact, we know from the experiments of Brunner and others that the bacteria are excreted in the sweat. The septic diarrhœa is combated with opium, tannin, subnitrate of bismuth, acetate of lead, enemas of starch paste containing tannin, opium, etc., but unfortunately they are usually without much effect. The diet of the patient should be one which is easily assimilated, and as nutritious as possible. Alcohol in the form of strong wines or whiskey should be given freely. Transfusion, which has been used by Hueter in the treatment of septicæmia, is not to be recommended.

§ 75. **Pyæmia (Pyohæmia) or Pus Poisoning.**—Pyæmia or pyohæmia (from *πῦον*, pus, and *αἷμα*, blood) was, until recently, understood to mean an infection by pus, a pus poisoning, caused by the presence in the blood of the elements of pus. In general, pyæmia is characterised by the development of multiple foci of suppuration (metastases) in the different organs, as a result of the wide distribution of the pyæmic poison, and by an intermittent type of fever. It has been stated before (page 363) that it is often impossible to draw a sharp distinction between pyæmia and septicæmia, and that both of these diseases, clinically as well as anatomically, frequently occur together (septico-pyæmia). Consequently it is becoming more and more a common practice to make no attempt at distinguishing between septicæmia and pyæmia, either clinically or anatomically. The same micro-organisms are found in both affections, and it is a secondary matter whether the infection leads to suppuration or not. It would be simpler to include both diseases under one name, such as pyo-septicæmia or septico-pyæmia.

Etiology of Pyæmia—Micro-organisms.—Koch has produced experimentally in rabbits a pyæmia which is similar to the pyæmia occurring in man. He states that this pyæmia of rabbits is excited by a specific coccus which differs from all other cocci, and in particular from the coccus of the cheesy pus found in rabbits.

It used to be believed that the pyæmia of man was due to a specific micro-organism, but this theory has been proved to be incorrect; and, in general, there are found in pyæmia the same micro-organisms as in septicæmia (see pages 363–367), which is a proof that the two diseases cannot be considered etiologically distinct. The common pus cocci are the ones most constantly present in pyæmia (see pages 321–326). Any acute abscess may give rise to

the disease. Under ordinary conditions the abscess is cut off by the inflammatory infiltration surrounding it from the adjoining healthy parts, so that the cocci cannot find their way out into the tissues and circulatory fluids of the body. If, however, the system is not protected in this manner, if the suppurating area is subjected to a certain amount of pressure, or if there is any considerable new addition of cocci to those already present, a general systemic poisoning from the cocci, with a constitutional febrile disease and the formation of suppurating foci in all the different organs—in other words, pyæmia—is easily produced. Clinically there are two main groups or forms of the pyæmic process. In one there is a large focus of suppuration, possibly in a joint or following a compound fracture, and starting from this focus there is a continuous invasion of the whole body by cocci, accompanied by a hectic fever and followed by death. In the second group of cases there is no large focus of suppuration, but instead there is only some small injury, an insignificant cutaneous abrasion, or a punctured wound, etc.; and following this single infection, there ensues, without any long-continued suppuration at the point of infection, a constitutional pyæmic process and death, though the primary injury may have cicatrised a long time previously. At the post-mortem examination there will be found in the internal organs the characteristic metastatic foci of suppuration. Cases of this description are due to bacteria which start from a single infection of the wound, multiply, and are carried off by the circulation and scattered throughout the body, and wherever they lodge they give rise to inflammation and collections of pus. In this worst form of pyæmia with metastases the ordinary pus cocci are present. Rosenbach found that the most frequent cause of pyæmia with metastases was the streptococcus pyogenes (see page 323), though typical examples of pyæmia have been known to follow infection by other cocci, the staphylococcus pyogenes aureus, for instance. In addition to the pyæmia due to cocci there is also a pyæmia due to bacilli, and essentially the same micro-organisms are present as in septicæmia, and hence the difficulty of distinguishing the two diseases etiologically. The course of pyæmia in man, as of the other infectious-wound diseases, varies with the virulence of the infecting micro-organisms, their number, the susceptibility of the individual affected, and the anatomical position and peculiarities of the point of infection. We know that the virulence of the same micro-organism is subject to variation, and that we can artificially weaken this virulence of the septic and pyæmic micro-organism; and it has been proved, by the experiments of Koch, Gaffky and others, that we can increase their virulence by transmitting the micro-organisms in question from one animal to another of the same species—for example, from man to man.

It occasionally happens that the origin of a pyæmia is not clear during the life of the patient as is true of septicæmia, and the disease is then called cryptogenic pyæmia or pyosepticæmia. In such cases the focus of the infection which gave rise to the pyæmia can usually be discovered at the post-mortem examination.

The Pathological Changes Occurring in Pyæmia.—The severe poisoning of the whole organism is the predominant feature of septicæmia, but in pyæmia the local inflammatory processes are characteristic. In

the first place, micro-organisms will be found in the vessels, in the blood, in all the various organs, and in the metastatic foci of suppuration (Figs. 275, 276). In the blood the micro-organisms are present in the plasma, and particularly in the white corpuscles, which in pyæmia as well as in septicæmia are destroyed in relatively large numbers. The bacterial inflammation of the walls of the veins, with the consequent formation of thrombi, which, under the influence of the cocci they contain, break down and suppurate, is a characteristic feature of pyæmia (see § 69, Phlebitis). Portions of the infected or suppurating thrombi are torn off and carried away by the blood current and lodge here and there as emboli, possibly in the pulmonary capillaries, and wherever they find lodgement they produce thrombosis and suppuration (metastatic abscesses.) Collections of micrococci and metastatic (embolic) abscesses may thus be found in the muscles of the heart, the endo- and pericardium, in the lungs, pleura, brain, liver, spleen, kidneys, in the joints, the marrow of the bones, the muscles, lymph glands, and, in short, in all the different organs. Occasionally a reddening like erysipelas makes its appearance in the skin, but it generally disappears after the lapse of a few days; or there may also be vesicles or pustules. If the pyæmia runs a more chronic course, the pathological changes are less pronounced; the local inflammatory processes, the metastatic abscesses, are not so numerous, or they occur in the stage of convalescence. The marked emaciation of the patient, the fever caused by the changes in the organs (see § 62), and the remnants of the earlier local inflammatory or suppurative processes, are characteristic of chronic pyæmia.

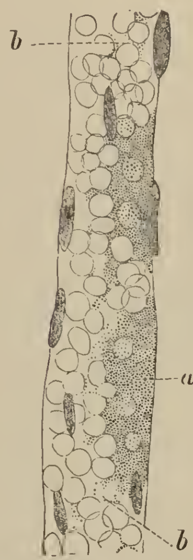

Fig. 275.—Blood-vessel in the cortical substance of the kidney, taken from a pyæmic rabbit: *a*, dense mass of micrococci on the inner wall, containing blood-corpuscles; *b*, small groups of cocci between the blood-corpuscles. × 700 (Koch).

Fig. 276.—Specimen from the liver of a soldier who died of pyæmia. The capillaries between the liver cells are filled with masses of micrococci (Klebs).

Sometimes, as in septicæmia, there occur cases of so-called cryptogenic pyæmia with extensive metastases, and it will be impossible to find the primary source of infection either during life or after death.

Occurrence of Pyæmia.—Since the advent of the antiseptic period of surgery, pyæmia has occurred much less frequently than it used to. Before the days of antisepsis many hospitals were notorious for the pyæmia and infectious-wound diseases which raged endemically within them, but now in these same hospitals the antiseptic method of treating wounds has caused the infectious-wound diseases to disappear entirely. The most certain way, then, of preventing pyæmia is to observe the strictest antisepsis and asepsis.

Clinical Course of Pyæmia.—*The symptoms of pyæmia* are characterised by the development of collections of micrococci and multiple metastatic suppurative processes starting in the wound or source of infection and involving all the different organs of the body, and by an intermittent type of fever with intercurrent chills. According to the nature of the wound the cases are divided into two main classes. In the first group there is somewhere a collection of pus—for instance in a joint—or it may be connected with a compound fracture, and from this focus the whole body receives constant invasions by cocci, and at the same time there is a remittent fever with intercurrent chills. In the second group of cases the disease originates from the single infection of some small wound, and not from a collection of pus which has been in existence a long time. In this second group the micro-organisms multiply in the system and spread through all parts of it, and wherever they find lodgement they excite inflammation and suppuration.

The pyæmic fever, which has been carefully studied by Billroth and Heubner, does not, as a rule, follow a regular course, but, in the main, is intermittent—that is, after a marked elevation of temperature there is a sudden fall to a normal or subnormal point, and the temperature remains down for a variable length of time (Fig. 277).

Pyæmia is usually ushered in by a rigour, and in its subsequent course chills are of more or less frequent occurrence, the temperature rising with greater or less rapidity after each chill to 40° C. (104° F.) or higher, and just as rapidly again dropping to the normal. The length of time that each chill lasts varies very much. If the temperature rises gradually there will be no chills.

The intermissions may be repeated every twenty-four hours or every other day, or less frequently. After several days have elapsed without any fever it may be thought that the pyæmia has terminated favourably, when suddenly there will be a fresh chill followed by high fever, and then it will be known that the disease is still active. This peculiarly irregular course of the pyæmic fever is due to the fact that from time to time micrococci and the products of their metabolism escape from some particular focus or collection of them into the gen-

eral circulation. When their metabolic products have again been excreted from the blood the fever ceases.

The condition of the pulse corresponds to the course of the fever, but König is right in stating that the pulse of a pyæmic patient still

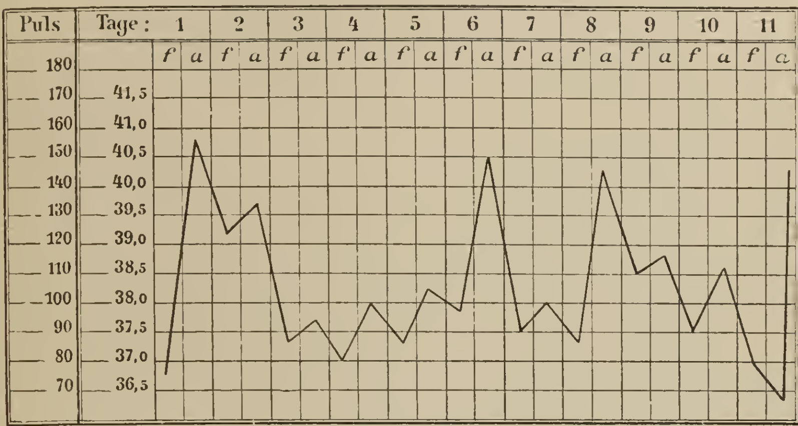

Fig. 277.—Temperature eurve of pyæmia.

remains rapid during the time when there is no fever, and never entirely falls to the normal rate. The general condition of the patient varies with the amount of the fever. The appetite is usually very poor; occasionally there is nausea or vomiting, and in the later stages there is apt to be a profuse diarrhœa. The urine ordinarily contains albumen and casts. Jaundice is common, and is sometimes, as in septicæmia, hæmatogenous, in consequence of the disintegration of the red blood-corpuscles; and in other cases it may be caused by pyæmic abscesses of the liver or by catarrhal swelling of the intestinal mucous membrane in the neighbourhood of the ductus choledochus. The other symptoms of pyæmia are, in general, caused by the metastatic inflammations in the internal organs, and vary greatly according to the extent and location of these inflammations. Metastases in the lungs give rise to hæmoptysis, to circumscribed catarrhal processes, to lobular pneumonia, extensive pulmonary abscesses, and to the different kinds of pleural inflammation. The metastatic processes in the abdominal organs, the liver, spleen, and kidneys, often give rise to so few symptoms that they cannot be diagnosticated during the life of the patient. Abscesses occur with the greatest frequency in the lungs and spleen, less often in the liver and kidneys. Metastatic joint inflammations are not uncommon. A large amount of albumen in the urine, with epithelium, casts, and an admixture of blood, indicate an acute metastatic nephritis.

If metastatic suppuration develops in the brain there will be corresponding symptoms of paralysis. Metastatic meningitis will present the picture of diffuse suppurative encephalitis.

The abscesses which may occur in the superficial organs, the lymph glands, parotid, joints, muscles, and subcutaneous cellular tissue, etc., are easily recognisable; they often cause no pain, and are accompanied with little inflammatory reaction, which is also the case with abscesses in the medulla of the bones. As in septicæmia, there is, in consequence of the disturbance of nutrition in the walls of the vessels, a tendency to capillary hæmorrhages; or, in consequence of the suppurative breaking down of a thrombus and the adjoining wall of the vessel, which may be situated within a focus of suppuration, hæmorrhages from the larger arteries and veins may take place, which will endanger the life of the patient. If the pyæmia starts from a granulating wound, it is sometimes noticed that the latter begins to suppurate less freely than before, the granulations become pale and flabby, and not infrequently break down or undergo diphtheritic changes.

The duration of a pyæmia is very uncertain. Generally it runs an acute course (eight to ten to twelve days), often a subacute (three to four weeks), less frequently a chronic course (two to three to five months). As in septicæmia, so also in pyæmia there are cases which apparently recover and then suddenly, after the lapse of months or a year or more, there occurs a fresh acute general infection starting from the old encapsulated pyæmic focus, to which the patient may succumb.

Prognosis of Pyæmia.—The prognosis of acute pyæmia is almost absolutely bad, and yet there are recorded cases of recovery in spite of internal metastases in the lungs, spleen, etc. The more frequently the chills are repeated, the more rapidly the strength fails, and the earlier the symptoms occur pointing to internal metastases, so much the more rapidly will the disease terminate in death. Chronic pyæmia finally kills the patient by exhaustion, unless the focus of infection that is present is subjected to proper surgical treatment.

Diagnosis.—In the diagnosis of pyæmia the irregular course of the fever, with intercurrent chills and the occurrence of metastases, are almost pathognomonic. Occasionally pyæmia is combined with septicæmia or with erysipelas, and then its course is masked by the other infectious-wound disease.

Treatment of Pyæmia.—Pyæmia is treated in essentially the same way as septicæmia. As in septicæmia, the local treatment of the source of infection is exceedingly important, and should be as energetic as possible—that is, every pyæmic collection of pus should be done away with at the earliest possible moment. All metastatic abscesses accessible

to surgical treatment should be opened on antiseptic principles and disinfected. But the treatment of fully developed pyæmia, as of septicæmia, is, for the most part, of no avail. It must, however, never be forgotten that we have a certain means of preventing both diseases by practising thorough antisepsis in the treatment of every wound. If the patient is long confined to bed, disturbances of the circulation, as a result of cardiac and respiratory weakness, are very apt to occur in the skin, followed by necrosis of the latter—in other words, bedsores or decubitus may appear, especially in those regions where the skin is closely superimposed upon the bones, as over the sacrum, the trochanters, scapulæ, and elbows. To avoid this complication, these areas of skin should be carefully protected from pressure by the use of air- or water-cushions, and they should be kept scrupulously clean by washing them with alcohol, etc. The treatment of bedsores after they have developed will be discussed under the subject of ulcers (see § 93, Diseases of the Skin).

§ 76. **Infection by Cadaveric Poison.**—All individuals who have much to do with cadavers or dead animal matter, and so all physicians, anatomists, butchers, cooks, etc., are liable, on the reception often of trifling injuries, to suffer from infectious inflammations of various sorts, which very often lead to fatal general poisoning. The so-called cadaveric poison is more or less identical with the poison of decomposition. But the bodies of all animals which have died from a specific infectious-wound disease, such as erysipelas, pyæmia, anthrax, rabies, etc., still harbour the specific bacteria which caused this infectious disease, and these bacteria remain capable of exciting the same disease for the first twenty-four hours after death. When decomposition of the dead body sets in, the specific bacteria of pyæmia, erysipelas, anthrax, etc., perish, succumbing in the struggle for existence with the bacteria of decomposition. Consequently there may be various poisonous substances in the cadaver, notably the excitants and products of decomposition, and also, in the period immediately following death, the excitants of specific diseases. Therefore it can be understood why the infections of wounds from dead bodies have very different clinical results, and that septicæmia and pyæmia, as well as specific diseases like anthrax and tuberculosis, are alike transmissible from cadavers. Infection with cadaver poison usually takes place through a small or punctured wound, an abrasion of the skin from a splinter or sharp edge of bone, etc., and frequently the injury is so trifling as not to bleed, and may be entirely overlooked. As a general thing it is better when the wound bleeds, as then any bacteria which may have lodged in it are apt to be swept out by the flow of blood.

In the first place, there are wound infections which run a very acute

course, particularly those in which the infection is from a septic cadaver. This may also occur in surgeons after they have operated upon a collection of foul pus in a living patient. The septic-wound infection may, in the worst cases, exhibit the following peculiarities: At the outset there is a small injury, which generally causes only a slight amount of pain, and then very soon there occur headache, nausea, general lassitude, a severe chill, and a rapid rise of temperature. In the worst cases, which are, however, not common, death may follow within two to three days, preceded by delirium and stupor, and yet the point where infection took place will not show any noticeable local inflammation. These are the cases of acute septicæmia which have been described in § 74. It is still a question whether these severe forms of septicæmia can be caused by infection from a non-septic cadaver—i. e., by infection with the usual cadaveric poison.

Comparatively often, after infection from a dead body, a circumscribed inflammation will begin in the neighbourhood of the wound, terminating in suppuration, and having a tendency to gangrene, with secondary lymphangitis, phlebitis, and purulent lymphadenitis, for example, in the epitrochlear and axillary glands. Sometimes the course of the disease is very protracted, and there are cases which act like chronic pyæmia. These latter are apt to occur after infection from the dead body of a patient who has died of pyæmia.

Cadaver Tuberculosis (*Verruca necrogenica*).—The so-called anatomical tubercle is a peculiar chronic form of infection from dead bodies, and is the name given to wart-like, moist, often ulcerating growths, which are particularly liable to occur upon the backs of the hands or the knuckles of those who habitually handle cadavers, such as anatomists, demonstrators, etc. The anatomical tubercle usually remains local, though there may be attacks of acute lymphangitis and lymphadenitis, with possibly the formation of abscesses. Baumgarten, Riehl and others have demonstrated that the anatomical tubercle is not the result exclusively of ordinary cadaver poisoning, as these investigators have found tubercle bacilli in the tubercles. Consequently it is an undoubted fact that some anatomical tubercles, at least, are forms of local tuberculosis.

There occasionally result from cadaver infection small abscesses and pustules without any injury of the skin having occurred; under these conditions the poisonous substances are lodged in the normal cutaneous pores, especially the sebaceous glands.

Zoönotic Erysipeloid.—In this class of cases belongs the so-called *zoönotic finger-erysipeloid*—chronic erysipelas or erythema migrans—which has been described on page 351.

Mention has been made of the fact that very dangerous, specific, infectious-wound diseases can be transmitted to man from the dead bodies of human beings and animals, particularly within the first twenty-four hours following death. This matter will be discussed again when we come to the subjects of anthrax, syphilis, etc.

Prophylaxis and Treatment of Cadaver Infection.—From these facts it follows that every one having much to do with dead human or animal bodies should use the greatest precautions. To *prevent* cadaveric infection, one should employ disinfecting washes of absolute alcohol and of one-per-cent. solutions of bichloride of mercury or three- to five-per-cent. solutions of carbolic acid. By this means the so-called anatomical tubercle can be avoided with certainty, and after it has broken out it can be caused to gradually disappear by the use of bichloride washes and dressings. If post-mortem examinations have to be undertaken upon bodies infected with pyæmia, septicæmia, anthrax, etc., or in case of small scratches or wounds of the hands, it is an excellent plan to cover the hands with carbolised vaseline, rubber gloves, etc.

If an injury is sustained during the examination the blood should be pressed out of the wound, or the latter should be sucked and then thoroughly disinfected, no matter how trifling it may be, with absolute alcohol and a one-fifth-per-cent. solution of bichloride of mercury, or a five-per-cent. solution of carbolic acid. These remedies are better than the application of caustic acids which form an eschar, such as nitric acid, which was at one time very frequently used. After many years experience as an anatomist, Lange advises that before undertaking an autopsy all cracks or scratches on the hands should be painted with tincture of iodine; and he has also found it very successful to adopt the same treatment for any wound received during the course of the autopsy, after it has stopped bleeding. If local inflammation or systemic infection should occur, either condition should be treated upon the principles which have been laid down in a previous chapter. Long and deep incisions should always be made at an early stage at the point of infection, and these should be followed by the continuous application of solutions of bichloride of mercury varying in strength from 1 to 500 to 1 to 1,000 of water. Morphine should be exhibited subcutaneously to alleviate pain.

§ 77. **Splenic Fever or Anthrax.**—Anthrax is an acute infectious disease caused by a specific bacillus, and is one of the most widely distributed and fatal of diseases, particularly amongst cattle, and it is not infrequently communicated from them to man. The name *splenic fever* is derived from the fact that animals afflicted with this disease have a very much enlarged spleen.

Etiology of Anthrax.—Accurate knowledge had been obtained about the origin of anthrax before anything was known about the etiology of the other bacterial infectious diseases. In 1849 Pollender and Brauell, working entirely independently of each other, discovered in the blood of cattle dying of anthrax, fine rod-shaped structures, and afterwards recognised their vegetable nature. Davaine was the first to prove that anthrax could not be excited in healthy animals by inoculating the latter with blood which contained no bacteria, but that it could be produced by inoculations with blood in which the bacilli were present (1863). These experiments were frequently repeated, and always with the same results, Pasteur, in particular, using blood which had been freed from formed elements by filtering it through porcelain. Robert Koch has furnished us with the most important facts concerning anthrax and its bacilli, and at present the latter are the best known of all species of bacteria.

Fig. 278.—Blood from a mouse with anthrax dried on a cover-glass, and stained with methylene violet. Red blood-corpuscles and anthrax bacilli. × 700 (Koch).

Fig. 279.—Strings of anthrax bacilli, from a three hours' old culture of the blood of a guinea pig in humour aqueus. × 650 (Koch).

Anthrax Bacillus.—The anthrax bacillus (bacillus anthracis) is a transparent rod, incapable of motion, possesses rounded ends, and is 3 to 10 μ long and 1·0 to 1·2 μ broad (Fig. 278). It is found in the blood of animals suffering from anthrax either singly, each bacillus by itself, or in filaments made up of two to six to ten little rods connected together (Fig. 279). The line of separation between the individual bacilli is plainly distinguishable, causing the anthrax filaments to assume a characteristic appearance. The bacillus is incapable of motion and is aërobic—that is, it requires the presence of oxygen to grow, the most favourable temperature being that obtained in a culture oven, and no development takes place below 15° C. or above 45° C. The gelatine is rapidly liquefied. Gelatine puncture cultures usually present the appearance illustrated in Fig. 280—that is, fine processes, thorns, or needles radiate from the line in which the puncture was made. On gelatine plates colonies develop with a notched, uneven border or a cone-shaped coil, from which filamentous extensions stretch out in all directions. On potatoes the bacillus forms a dry, white layer (Fig. 281) ; on agar there develops a greyish, slightly glistening covering. In all artificial nutritive media long filaments are formed made up of many hundreds, or even thousands, of separate bacilli. When the nutrition has become exhausted from the culture medium, provided oxygen is present and the temperature remains between 18° and 40° C., the bacilli develop spores, which have the shape of small drops with a strongly refractive power. The best spores form in temperatures between 20° to 25° C. At the most favourable temperature the spores are formed in twenty-four hours; at 21° C. it takes seventy to

seventy-five hours. After the spores have fully formed the bacillus breaks up, and the spores are liberated and can then, if they lodge upon a proper nutritive medium, each grow into a bacillus. The powers of resistance possessed by anthrax spores vary with the particular noxious influence to which they may be subjected, a five-per-cent. solution of carbolic acid, for instance, killing them in two to thirty to fifty days, while steam at a temperature of 100° C. will destroy their vitality in three to ten to twelve minutes. If bichromate of potassium, in the proportion of 1 to 2,000–5,000, is added to a nutritive medium containing anthrax, such as bouillon, the bacilli will lose their power of forming spores. The same result can be obtained by subjecting bouillon cultures containing carbolic acid (in the proportion of 8 to 20–10,000) for eight days to a temperature ranging between 30° and 33° C. Anthrax bacilli thus rendered incapable of forming spores lose none of their virulence when used for inoculating purposes; nevertheless, the species never regains its lost power of developing spores. There is some difference between the shape and the appearance of the cultures of the ordinary anthrax bacilli and those rendered incapable of spore formation. This fact has peculiar significance, showing, as it does, that the bacteria exhibit marked differences depending upon the medium in which they develop, and that they cannot be distinguished from one another without taking other things into account besides their shape and the appearance of the culture. When they have exhausted the nutritive principles from any medium in which they are growing the bacilli die or take on involution forms. The anthrax bacilli develop no spores in the living animal body and in the undecomposed cadaver, as this process will only take place when the access of oxygen is unhindered.

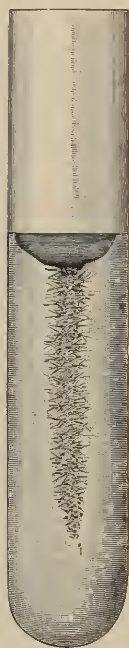

Fig. 280. — Stab culture of anthrax in gelatine. Eight days old.

The best way to study the development of the bacilli under the microscope is to place a drop of the ordinary culture bouillon containing the bacilli in the concavity of a slide which has been hollowed out for the purpose.

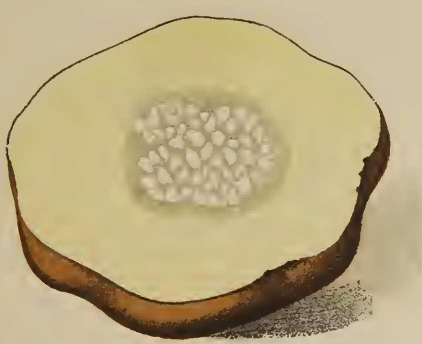

Fig. 281.—Pure culture of anthrax bacilli upon a boiled potato.

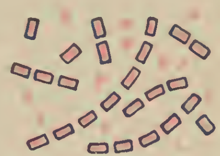

Fig. 282.—Anthrax spores stained red with fuchsin, some free, others shut up within bacilli which have been stained blue with methylene blue.

Artificial Attenuation of the Virulence of Anthrax Bacilli.—The virulence of anthrax bacilli can be weakened or attenuated in various ways, such as subjecting them to a high or low temperature, or making the culture grow for a long time—twenty-four days or so—at a temperature of 42° to 43° C. By treating them in some such manner it is possible to render anthrax bacilli entirely innocuous (Koch, Löffler, etc.). The weakened or attenuated bacillus forms metabolic products which differ from those of virulent anthrax, the former producing, for example, acid in an artificial nutritive medium, the latter causing a reduction of the nutritive medium. Pasteur tried to render cattle and sheep unsusceptible to anthrax by inoculating them with bacilli which had been attenuated by cultivation at a temperature of 42° to 43° C. The principle is the same as in vaccination with cow-pox for protection from variola; but Pasteur's inoculation with attenuated anthrax does not always seem to give immunity from infection occurring in the ordinary way through the intestine. Hankin, in Koch's institute, isolated a poisonous albumose from anthrax cultures which produced in mice and rabbits immunity from anthrax, when exhibited in very small doses. The virulence of anthrax bacteria can be weakened by various antagonistic bacteria, such as the cocci of erysipelas, the bacillus pyocyaneus, Friedländer's pneumococcus, the micrococcus prodigiosus, the bacillus putridus and albus, etc. Also, sterilised cultures of these antagonistic bacteria exert, according to Buchner, a restraint upon the development of anthrax bacilli, whence it follows that the chemical substances derived from the above-mentioned bacteria, are the active restraining agents. This fact has been made use of for therapeutic purposes, and also for obtaining immunity from anthrax infection. Emmerich, Di Mattei and Pawlowsky inoculated animals (rabbits) with the erysipelas coccus, and they became afterwards unsusceptible to anthrax. The discovery made by Wooldridge is exceedingly interesting. He found that injections of a solution of fibrinogen which had been used for the cultivation of anthrax made animals immune from this disease, and that the same result could also be obtained by using fibrinogen which had been subjected to a slight chemical change without making use of anthrax bacilli. Charrin and Bouchard have checked anthrax at its inception in animals by inoculating them with the bacillus pyocyaneus, and have cured the disease.

Most authors are of the opinion that anthrax bacilli lose some of their virulence after having passed through the body of an animal which is not susceptible to them. On the other hand, Malm was able to show that their virulence is increased.

Occurrence and Origin of Anthrax.—Anthrax is widely distributed in many countries, such as Russia, Siberia, Hungary, India, Persia, and in certain districts of France and Germany, and yearly works destruction in herds of cattle, particularly during the hot summer months, while in winter it ceases its ravages. In England and North America anthrax is not so common. The anthrax bacillus has not yet been proved to exist outside of the animal body. In grazing animals (sheep, cattle, horses) the bacillus is most commonly taken into the system through the intestine, less often by cutaneous inoculation. Mice, guinea-pigs and rabbits are easily infected by inhaling the spores, and are not readily infected through the intestine. In man, anthrax is communicated particularly by infection of small cutaneous wounds (malignant

pustule), less often through the lungs and intestine. The anthrax bacilli multiply very rapidly in the animal body, and are found not only at the point of infection—the malignant pustule, for example (Fig. 283)—but also in the blood-vessels, where they exist in vast numbers. They are also present, immediately after the infection takes place, in the lymph and the chyle when the infection occurs through the intestine. In the malignant pustule the anthrax bacilli will be frequently found enclosed within cells, a fact which cannot be considered as supporting Metschnikoff's theory of phagocytosis (see pages 272, 273), as the bacilli were probably dead before they were taken up by the cells. The infected organism usually succumbs very soon in consequence of the rapid multiplication of the bacilli and the poisonous products of their metabolism. The toxic products (albumoses and bases) of the anthrax bacilli have been studied by Hankin, Lando Landi, and others.

FIG. 283.—Anthrax bacilli from a malignant pustule of the skin. The bacilli are stained with gentian violet, and the tissues with Bismarck-brown. × 300.

Natural Immunity of certain Animals from Anthrax.—Dogs, pigs, and the majority of birds, are immune from anthrax; also rats, for the most part, and frogs under ordinary conditions. But if a frog, in whose lymph sack are placed anthrax spores, is put in an incubation apparatus, he will quickly die of anthrax. According to Rohrschneider, 28° C. is the lowest limit of temperature at which anthrax bacilli will develop within a frog's body. According to Crookshank, pigs may acquire anthrax. Ssawtschenko stated that after the spinal cord is divided in doves they are no longer immune from anthrax. In general, the immunity which various animals possess towards anthrax does not appear to be complete, as the bacilli can gradually become accustomed to develop in media which are unsuitable for them.

FIG. 284.—Anthrax bacilli in the capillaries of an intestinal villus (rabbit), stained with methylene violet, and then treated with potassium carbonate. × 700 (Koch).

It has been proved by Birch-Hirschfield and others that anthrax bacilli can be transmitted from the mother to the fœtus *in utero*. The bacilli, as it were, grow into the fœtal placenta, aided by changes in the walls of the vessels, in the tissues surrounding the vessels, and in the epithelium of the villi. The healthy placenta does not normally permit the passage into and through it of micro-organisms or other formed elements, and the filter only becomes pervious

when affected by pathogenic bacteria which have gained access to the placenta.

Staining of Anthrax Bacilli.—The anthrax bacillus can be rapidly stained by aqueous solutions of the aniline dyes, and also by Gram's method. The spores are best stained at a high temperature by means of Ehrlich's aniline-water-fuchsin solution or Ziehl's solution containing carbolic acid. Instead of Ehrlich's fuchsin solution, a correspondingly made solution of gentian violet can be employed for staining the spores. After decolouration of the substance of the bacilli the spores are stained with Bismarck brown.

The Course of Anthrax in Animals.—Anthrax in domestic animals may take one of three courses: 1, The apoplectiform anthrax (anthrax acutissimus), which lasts from a few minutes to several hours; 2, the acute anthrax (anthrax acutus), lasting from a few hours to several days; and, 3, the subacute form of anthrax (anthrax subacutus), of longer duration. There is no period of incubation, or it may occupy three to five days. In the more common apoplectiform variety of anthrax (cattle, sheep) the animals which previously had apparently been in perfect health fall down as though struck with a blow, and die often in a few minutes with convulsions, cyanosis, and dyspnœa. According to Bollinger, acute anthrax in cattle and horses begins with loss of appetite and a chill, followed by a remittent or intermittent high fever (41° C.—105·8° F.—and higher); there are almost always spasms, particularly clonic spasms of the extremities. These symptoms come on in the form of paroxysms. The subacute form of anthrax, the anthrax carbuncle, is characterised by carbunculous and erysipelatous swelling occurring in different places in the skin, particularly in the region of the hind feet, while there is only a slight constitutional disturbance. The carbuncle begins to be absorbed frequently after the lapse of a few days, and an eschar and ulceration develop only exceptionally. In about sixty to seventy per cent. of the subacute cases (in cattle and horses, for example) death follows with dyspnœa and convulsions.

Anthrax in Man.—Anthrax occurs in man mainly by transmission of the anthrax bacilli or their spores from a diseased animal, and hence those persons are particularly liable to the disease who in their occupation come in contact with infected animals or parts of animals. Such persons are shepherds, farmers, butchers, veterinary surgeons, workers in leather (furriers, and those who handle skins), and people who are employed in the preparation of horse-hair, wool, and paper.

The so-called *rag-sorters' disease*, which runs a rapidly fatal course, presenting the appearance of pneumonia with typhoid or septic symptoms, and attacks people who sort and tear rags in the manufacture of paper, is occasionally primary anthrax of the lungs caused by inhaling anthrax spores. Kraunhals states that the disease is also caused by the bacillus of malignant œdema. There are naturally various micro-organisms in rags. O. Roth describes three kinds of pathogenic bacilli: Bacillus I is like the bacterium coli, Bacillus II like the proteus hominis, and Bacillus III like Hauser's proteus vulgaris (see page 366).

Enderlen's experiments in the Pathological Institute at Munich show that breathing in the spores of anthrax is much more dangerous than their ingestion in food. All "inhalation animals" perished of anthrax, while of the animals infected through food some remained alive. Anthrax is also caused in man by eating the flesh, milk or butter obtained from animals affected with this disease. It may also be transmitted by insects (flies) which come in contact with animals having anthrax, and the poison may be communicated from man to man—for example, at an autopsy. The disease starts either by inoculation of the bacilli or of their spores into the skin (it may be a very small interruption of continuity), or by inhalation of the poison, or by its introduction with the food into the alimentary canal. The cases of so-called intestinal mycosis recorded by E. Wagner and others are really cases of true anthrax disease. In general man is not very disposed towards anthrax. Marchand observed anthrax in a pregnant woman with fatal infection of the child. Lingard, experimenting with pregnant rabbits, caused an infection of the fœtus, and found that in some cases the fœtus alone became diseased, in others the mother also. Sections through the placenta plainly showed the passage of the anthrax bacilli from the fœtal to the maternal blood-vessels. Birch-Hirschfeld's recent observations, which were mentioned before, are very interesting, proving, as they do, the transmission of the anthrax bacilli from the maternal into the fœtal circulation. If an abundant development of anthrax bacilli takes place in the placenta, the bacteria actually grow into and through the fœtal portion of the placenta in a manner similar to that in which, after inhalation of anthrax spores, the bacilli enter the pulmonary vessels, as was demonstrated by Buchner's experiments.

The course which anthrax takes in man varies according to whether the infection takes place externally or internally. When infection occurs through the skin there is an incubation period of three to six days, and then at the point of entrance there develops a burning or itching red nodule with a reddish or bluish bleb, which soon breaks and dries up, forming a scab. The skin in the neighbourhood of the scab then usually becomes swollen, and sometimes more blebs form. The primary nodule at the point of infection varies from the size of a pea to that of a nut. Ordinarily the induration and œdematous swelling extend very rapidly in all directions from the primary nodule, and the adjoining lymphatic glands become enlarged. After the local symptoms have continued some forty-eight to sixty hours the constitutional manifestations of the disease begin (high fever, great weakness, delirium, diarrhœa, severe vague pains, etc.). If there is a fatal termination, death occurs very often with symptoms of collapse, generally

after the disease has lasted five to eight days. If there is a favourable termination the scab is sometimes cast off by a process of suppuration. In other cases there is observed a diffuse, erysipelatous form of carbuncle (Virchow, Bollinger)—for example, after infection by a fly-bite, and also when the infection has taken place internally. According to E. Wagner, the course of anthrax when the infection has taken place from the intestine is characterised by the suddenness of the onset and its rapid progress, with vomiting, diarrhœa, cyanosis, and subsequent collapse. When the infection takes place through the lungs, as in the above-mentioned rag-sorters' disease, there is observed a pneumonia, with typhoid or septic symptoms, and for the most part a rapidly fatal course. The autopsy in man reveals essentially the same changes as in animals. There are immense numbers of anthrax bacilli in the blood-vessels, and particularly in the capillaries (Fig. 284).

The Diagnosis of Anthrax, when infection has occurred through the skin, is made chiefly from the characteristic appearance of the malignant pustule, and from the patient's statements concerning his occupation, the origin of the pustule, etc. If necessary, the diagnosis can be cleared up by microscopical examination of the carbuncle. For making the diagnosis when the infection takes place from within, we must refer the reader to the text-books on internal medicine.

Prognosis.—The prognosis of anthrax in man, when infection takes place externally, depends mainly upon whether energetic surgical treatment is undertaken early enough. Lengyel and Koranyi, by adopting suitable local treatment, lost only thirteen out of one hundred and forty-two cases of anthrax. Patients with anthrax resulting from internal infection (intestinal, pulmonary) very rarely recover.

The Treatment of Anthrax.—In the treatment of anthrax in man the fact that the disease remains local a longer time than in animals is of the greatest importance. If the patient comes under observation early enough, it is our duty to destroy the point of infection as rapidly and thoroughly as possible—for instance, by extirpation, by making an eschar with the Paquelin, by cauterisation with nitric acid, etc. According to Koch, bichloride of mercury is the most effective poison for anthrax bacilli, being capable of killing them when used as dilute as 1 part to 300,000 of water. Consequently it is an excellent plan to use in and around the point of infection injections of one-tenth-per-cent. bichloride, or two to five per cent. carbolic acid (Raimbert and others), or dilute tincture of iodine (one to two of water, Davaine). In suitable cases, which come under treatment at an early stage, with anthrax infection located in an extremity, the latter can be tied off by an elastic tourniquet (Nissen). When general infection has occurred, as

shown by the presence of bacilli in the blood, little success can be expected from any effective internal treatment, such as with iodine, quinine, carbolic acid, etc., though Russian authors in particular have obtained very satisfactory results by the energetic subcutaneous and internal administration of carbolic acid (0·5 gramme of carbolic acid internally and energetic injections into the pustule). The future must decide whether it is possible in man, as in animals, to prevent anthrax or to cure it, by the inoculation of other kinds of bacteria (see page 384).

Symptomatic Anthrax.—Symptomatic anthrax (*charbon symptomatique* of the French) is a disease similar to anthrax, affecting cattle, which occurs endemically and mostly during the warm months of the year in many regions, notably the Bavarian Alps, Baden, Schleswig-Holstein, etc., and has long been confused with anthrax. Symptomatic anthrax has not hitherto been known to occur in man. The disease has been studied by Bollinger, Kitasato, and others. It is characterised by the formation of irregularly outlined, emphysematous, crackling swellings of the skin and muscular tissue, particularly on the thigh, and by a peculiar reddish-black discolouration of the diseased muscles. In the bloody serous fluid at the focus of the disease there is found a characteristic bacillus, which Kitasato was the first to obtain in pure cultures upon a solid nutritive medium. By inoculating animals with this bacillus Kitasato excited typical symptomatic anthrax.

FIG. 285.—Bacilli of symptomatic anthrax. Spore-bearing rods from a culture in agar. Cover-glass preparation, stained with fuchsin. × 1000 (Fränkel and Pfeiffer).

The *bacillus* of symptomatic anthrax (Fig. 285) is a rather large, slim, actively moving rod with plainly rounded ends, generally occurring singly, occasionally in pairs, but never in long filaments. It is strictly anaërobic, and when brought in contact with the oxygen of the air soon perishes. It grows at ordinary temperatures above 18° C., but best in the incubator. The spores form large, strongly refracting bodies, rather long, and are placed eccentrically at the end of the rod (Fig. 285). When the spores become free the rest of the bacillus speedily dies. The spores, which have great powers of resistance, do not form in living animals, but do so in dead bodies and in artificial cultures. It is worth noting that the older cells, or those which have grown in media unsuitable for them, have a tendency to develop involution forms, which sometimes take the shape of large, plump, spindle-like segments enlarged in the centre, and revealing a granular cloudiness and an irregular contour.

In gelatine to which has been added grape sugar or some other reducing substance there develop within a few days spherical masses, which rapidly liquefy the nutritive medium (Fig. 286). In stab cultures, made in a large amount of gelatine, a cloudy, grey liquefaction takes place in the most deeply

placed parts, with the evolution of gas having a characteristic acid odour. Agar, at the temperature of the incubator, becomes filled with bubbles of gas even after the lapse of twenty-four hours. In bouillon, white flakes develop at the bottom of the vessel, accompanied by the formation of gas. When cultivated at a temperature of 42° to 43° C., the virulence of the bacilli is rapidly caused to disappear. The spores, particularly when subjected to high temperatures, lose their virulence; but if placed in a twenty-per-cent. solution of lactic acid, and then injected into susceptible animals, they can be made to regain their virulence, and that, too, in an increased amount. By inoculating susceptible animals with pure cultures the animals quickly die of symptomatic anthrax with the above-described symptoms. Under natural conditions, the disease occurs, in the majority of cases, from infection of small wounds, particularly of the extremities, less often from infection through the lungs or intestine. The poison is conveyed especially by the spores, as the bacilli quickly perish when exposed to the air. It is possible in various ways to obtain immunity from symptomatic anthrax, and for this purpose "vaccination" with suitable "vaccine" is very worthy of recommendation.

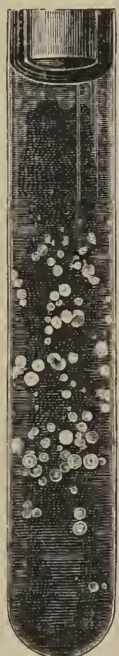

Fig. 286.—Bacilli of symptomatic anthrax. Pure culture four days old, after scattering the inoculating material about in grape-sugar gelatine; unstained; natural size (Fränkel and Pfeiffer).

The bacilli of symptomatic anthrax are stained in the ordinary way. The little rods, when subjected to Gram's method, lose their stain again. The spores cannot be stained by aqueous solutions of the aniline dyes, but readily take the double stain.

§ 78. **Glanders or Farcy** (*Malleus*).—Glanders is an infectious disease due to bacilli, primarily occurring, by preference, in horses and asses, and is transmissible to man and all domestic animals, with the single exception of cattle. The disease is characterised by the presence of peculiar small and large nodules, particularly in the mucous membrane of the respiratory tract, and in the skin, with secondary metastatic nodules in the internal organs (spleen, liver, kidneys, testicle, bones, etc.).

Löffler and Schütz demonstrated four years ago the presence of the characteristic bacilli in the glanders nodules, and made pure cultures of the bacilli upon artificial nutritive media, and produced typical glanders by inoculating various animals with these cultures. Israel, Kitt and Weichselbaum have also found the same bacilli in glanders, and have successfully inoculated other animals with them, so that there can be no doubt that these bacilli are the cause of the disease.

Glanders Bacilli.—The *glanders bacilli* (Fig. 287) are slim rods similar to tubercle bacilli, but more regular as regards their size, and somewhat broader

than the latter. They possess no inherent power of motion. The bacilli, like most of the pathogenic bacteria, are facultative anaërobic, and can be cultivated in the necessary nutritive medium at temperatures ranging between 25° and 40° C., and in the presence of oxygen. Upon potatoes there forms, at the ordinary incubator temperature, in the course of about two days, a yellowish, honey-like layer, which afterwards gradually becomes darker, varying from brownish to dark red. Upon agar the colonies form a whitish shining layer, and upon blood serum, which does not become liquefied, a clear, transparent covering in the form of drops, which later coalesce. The formation of spores by the glanders bacillus has not yet been demonstrated, but is considered probable by Löffler, Baumgarten and Rosenthal. Prolonged cultivation upon artificial nutritive media causes the glanders bacillus soon to lose its virulence. By inoculation of pure cultures of glanders bacilli upon susceptible animals (horse, ass, goat, cat, field mouse, house mouse, guinea-pig), the typical form of glanders is produced, the glanders bacilli being mainly found in the centre of the specific glanders nodules. Less susceptibility to glanders is evinced by hogs, sheep, rabbits, and dogs, with the exception of young dogs, which according to Flügge, are very susceptible to the disease. Cattle, house mice, white mice and rats are entirely unsusceptible. Field mice die in from three to four days after an artificial subcutaneous infection with glanders; guinea-pigs only in the course of several weeks. Leo states that white mice lose their natural immunity and become susceptible to glanders if they are made artificially diabetic by feeding them with phlorizin. The richer the blood of a particular animal in oxygen, the less able is the glanders poison to develop (Sanarelli). By continuous transmission of glanders bacilli from one animal to another it is possible to cause a remarkable increase in their virulence (Gamaléia). Babes has obtained from glanders cultures a toxalbumen ("mallein") which causes no local disease, but does cause symptoms of poisoning (fever, cramps, nephritis, marasmus).

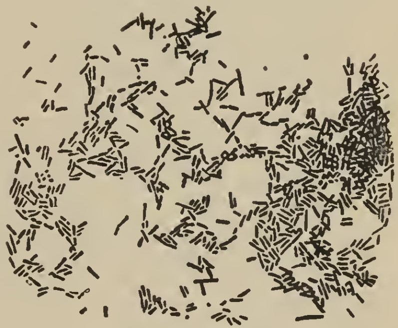

Fig. 287.—Bacillus of glanders. Pure cultures upon glycerine-agar, teased specimen stained with carbolic-fuchsin. × 100 (Fränkel and Pfeiffer).

The bacilli exist in the specific new tissue formations partly singly and partly in irregular collections or bunches of several parallel rods. The glanders preparations, or rather the glanders bacilli, are stained with concentrated alkaline solutions of methyl blue. They are then treated with greatly diluted acetic acid, washed in alcohol, and embedded in oil of cedar. Glanders bacilli cannot be stained by Gram's method. Amongst the recent methods of staining the following are particularly good: Weigert's aniline method, Unna's dry method, and the method of R. Kühne (sections placed for six to eight hours in carbolised methylene blue, then decolourised in acetic acid, and again in distilled water, dried upon the slide, clarified with xylol and embedded in Canada balsam).

Noniewicz recommends the following combination of Löffler's and Unna's staining methods: 1. Place the section taken from alcohol in Löffler's solution of methylene blue for from two to five minutes. 2. Wash in distilled water, and stain for from two to five seconds in seventy five parts of one-half-per-cent. acetic acid and twenty-five parts of one-half-per-cent. tropæolin. 3. Wash in distilled water. 4. Dry upon the slide, apply a drop of xylol, and examine in xylol and Canada balsam.

According to Noniewicz, glanders is caused partly by bacilli and partly by a coccus form. The round bodies are found particularly in subacute and chronic glanders.

Glanders infection, under natural conditions, generally occurs through some small injury of the skin or mucous membranes, and by inhalation. Babes has produced glanders in guinea-pigs by rubbing very virulent glanders bacilli into the sound skin; whence it follows that glanders bacilli are also able to penetrate into the hair follicles of the uninjured skin.

Glanders in Animals.—Glanders occurs in horses and other animals in the form of small or large nodules, or as a diffuse infiltration. The glanders nodules appear especially upon the mucous membrane of the respiratory tract and upon the skin. The nodules occurring in the mucous membrane of the respiratory tract, especially that of the nose, the larynx, and trachea, vary between the size of a grain of sand and a pea. At the outset they have a greyish-white or greyish-yellow colour, and appear singly or in groups and are surrounded by a red areola. From a suppurative breaking down, often within a few days, there result proportionately large ulcers, which usually enlarge rapidly by necrosis of the surrounding parts, extending also deeply into the subjacent tissues. In the lungs the glanders nodules are similar to tubercular nodules, appearing partly as lobular foci of inflammation and partly as interstitial nodules. The pulmonary glanders nodules occur, according to Bollinger and others, partly from direct aspiration of the glanders poison and partly as a result of embolism. In addition to the circumscribed glanders nodules, there are also found in the lungs diffuse infiltrations.

Upon the skin there occur, in the cutaneous form of glanders, small (miliary) or large nodules, accompanied by a rapid suppurative breaking down, and the formation of ulcers which quickly extend and also lead to inflammation of the lymphatic vessels and glands. Cutaneous glanders in rare cases may also occur, by an embolic process, secondarily to primary glanders of the respiratory mucous membrane. As was mentioned before, secondary glanders may also be found in the spleen and liver and in the bones, less often in the kidneys and testes, as a result of embolism.

The course of glanders may be acute or chronic, in the former terminating in death in six to twelve days; the latter, the more common form, may last for years.

Glanders in Man.—The transmission of glanders to man does not take place very frequently. Individuals—such as butchers, hostlers, cavalry soldiers, veterinary surgeons, etc.—who come in contact with animals, especially horses, which have glanders, are particularly apt to contract the disease. In man the disease takes the form of glanders of the conjunctiva, less often of the nasal mucous membrane, and particu-

larly glanders of the skin, originating in some insignificant injury, especially about the face and on the hands. In man also, as in animals, glanders may run an acute or chronic course, and there may develop the above-described glanders nodules and ulcerations at the point of infection, and secondary nodules in the internal organs as a result of embolism. Acute glanders runs a course marked by severe typhoid, septic manifestations, and sometimes it may resemble acute articular rheumatism. The disease not infrequently begins with a general feeling of malaise, and pains in all the limbs, in the joints and in the back. In conjunction with a high fever there develop at the point of infection typical glanders nodes which break down and ulcerate. Upon the skin pustular eruptions appear, which change into phagedænic ulcers having a dirty, lardaceous base. Birch-Hirschfeld saw pemphigus-like blebs upon the skin of the nose and cheeks, with rapid destruction of the greater part of the skin of the face (Fig. 288). In cutaneous glanders there are also not infrequently observed diffuse erysipelatous inflammations, and particularly lymphangitis and phlegmonous infiltrations of the subcutaneous cellular tissue, terminating in suppuration or ulcerative destructive processes. The secondary foci of glanders, particularly those in the internal organs, bear in acute glanders a close resemblance in every respect to pyæmic foci of pus, in chronic glanders to cheesy formations.

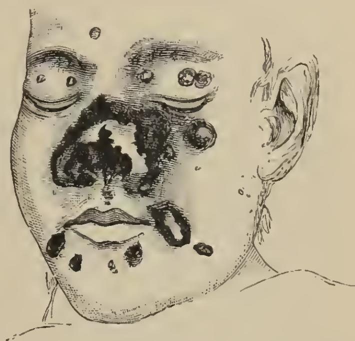

FIG. 288.—Acute glanders in man eight days old. Well-developed ulcerations of the skin of the face (Birch-Hirschfeld).

The above-described affection of the nose so characteristic of glanders in the horse, is not so frequently observed in man, and occasionally it first makes its appearance rather late in the disease. Acute glanders is accompanied by high fever, and runs a regularly fatal course within days or weeks, in consequence of the increasing systemic infection, with the formation of secondary nodes or abscesses in the internal organs as well as in the muscles and subcutaneous cellular tissue. Chronic glanders in man has hitherto been less accurately observed. König gives its average duration as four months. It runs a course essentially analogous to the above-described chronic glanders in the horse. Birch-Hirschfeld calls attention to the resemblance of chronic glanders to syphilitic and tubercular disease. According to König, the mortality of chronic glanders is about fifty per cent.

Diagnosis of Glanders.—The diagnosis of glanders in primary infection of the skin and nasal mucous membrane is usually not difficult, in consequence of the characteristic behaviour of the glanders nodes taken in conjunction with the occupation of the patient. Internal glanders of the trachea and lungs may often be first recognised when secondary affections of the skin occur, or when the characteristic glanders bacilli are demonstrated in the sputum. The demonstration of the bacilli in every case is, of course, of the greatest diagnostic importance. A good method for quickly diagnosing glanders consists in mixing the suspected secretion with water, and then injecting it intraperitoneally into male guinea-pigs. If it is really glanders, after the lapse of two to three days there occurs a swelling of the testicles, which increases during the next few days. In glanders it is of the greatest importance for the patient and his surroundings that the disease should be recognised as early as possible and energetically treated.

Treatment of Glanders.—The treatment of glanders can only be successful when the point of infection can be destroyed at a very early period by surgical means—either by extirpation, by the Paquelin or galvano-cautery, or by strong caustics (nitric acid, chloride of zinc), etc. The remainder of the treatment is symptomatic, and consists mainly in an energetic local treatment of the glanders focus by incision. Inunctions of mercurial ointment (two to three grammes a day) have been repeatedly used with success. Iodine and arsenic have been recommended internally.

§ 79. **Foot-and-Mouth Disease** (*Aphthæ Epizoöticæ*).—The foot-and-mouth disease is, according to Bollinger, an acute infectious disease which is transmitted exclusively by infection from one animal to another. This disease, which is observed particularly in cattle, sheep, swine, and goats, less often in horses and dogs, is characterised by moderate febrile constitutional symptoms, and by the formation of blebs and ulcers upon the mucous membrane of the mouth (stomatitis aphthosa), in the clefts of the hoofs, and on the udder. The means of infection—that is, the variety of micro-organism—is not yet known. Bender and Bollinger found in the ulcers and aphthæ micrococci and small rods. For the poison to enter the body, an injury, according to Bollinger, is not necessary; it clings to the uninjured epithelial layer of the cavity of the mouth or enters the system through the lungs, and probably also with the food. The disease is very contagious. The course of the foot-and-mouth disease is, as a rule, favourable, its duration, according to Bollinger, being usually twelve to fourteen days, rarely less. It generally terminates in recovery, and only young and cachectic old animals occasionally succumb to the disease if surrounded by unfavourable conditions.

Occurrence of the Mouth-and-Hoof Disease in Man.—The *transmission* of the disease to man occurs, according to Bollinger, most frequently by drinking the uncooked milk of diseased cows (Hertwig, Jacob), or by infection of a wound, particularly on the hands of butchers, or as a result of milking cows with a vesicular eruption on their udders, or by contact with the saliva of animals having the disease. Man is only moderately susceptible to the poison.

The *symptoms* of the disease in man—for example, after infection through milk—consist in an ulcerative stomatitis, a catarrhal gastro-enteritis, accompanied by fever, and frequently in a vesicular eruption upon the hands, the face, and other portions of the body. If the poison is transferred through a wound—for instance, in slaughtering or milking an infected animal—the hand and forearm become swollen, vesicles form, and the patients complain at the same time of pain in the mouth and dysphagia; and later vesicles or pustules make their appearance on other portions of the skin, particularly on the face. The disease lasts five to eight days; and only when the ulcers in the mouth and on the hands take on a virulent character and heal slowly does the affection continue for two to four weeks. Secondary phlegmonous-suppurative inflammations occasionally make their appearance.

In a great majority of the cases, according to Bollinger, the disease terminates in recovery, and only rarely, particularly in weak infants, causes death.

Treatment.—The treatment is essentially dietetic. Care should be taken to use only healthy milk. If the stomatitis is intense, it is an excellent plan to swab the mouth out repeatedly with a borax solution, and to employ mild cauterisation of the erosions and ulcers with silver nitrate in the form of a stick. The vesicular eruptions on the skin should be treated with ungt. lithargyr. Hebræ,* vaseline, boro-glycerine ointment, and particularly by dusting them with bismuth, iodoform, or oxide of zinc with starch (one to five to ten).

§ 80. **Hydrophobia** (*Lyssa, rabies*).—Hydrophobia is an acute infectious disease which occurs chiefly in the dog and related species of animals—wolf, fox, jackal, hyena. It consists essentially in a disease of the central nervous system, and is characterised by a long and extremely variable period of incubation.

Etiology of Rabies.—Rabies originates in a manner similar to syphilis—that is, by direct transference of the poison from the bearer to the receiver. The poison only takes root when inoculated into an injury of the skin or mucous membranes.

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* Unguentum diachylon.

Rabies is almost always transmitted through the bite of a rabid animal, by which the poison is directly inoculated into the wound. The experiments of Roux and Nocard show that infection may even result from a dog which at the time when he bites or licks an individual is entirely healthy, but later becomes mad. According to Novi, the poison of rabies may also be transferred to animals by midges and flies. Decomposition does not seem to destroy its virulence very soon. In dead animals decomposing in the air, the virulence, according to Travali and Brancaleone, could not be found after twenty-one days. In buried animals, the nervous centres were, in some instances, found virulent even after the lapse of forty-eight days; in other cases every trace of virulence had disappeared thirty-eight days after burial. The poison of rabies is destroyed by the digestive fluids. Zagari states that the virus of rabies loses its virulence very quickly when in contact with oxygen or air, as it also does in a dry medium and when the temperature is somewhat elevated; but in a space devoid of air, in carbonic acid, in a damp medium, and at low temperatures, it remains active for a long time. The poison of rabies, according to Pasteur, is always present in the fresh saliva, the blood, the spinal cord, and in the brain, salivary and lachrymal glands, the pancreas, and perhaps the mamma of animals affected with hydrophobia. Bombicci has also found that the suprarenal capsules are always virulent. Di Vestea, Zagari, and Schaffer have shown that the rabies poison is spread throughout the body by the nerves, in addition to the blood and lymphatic vessels, and this nervous distribution of the poison is the essential factor in causing the diffuse myelitis of the central nervous system. The views upon the microbe of rabies are still divided. Gibier, Brigidi and Bianchi think that a micrococcus is the cause of hydrophobia, whilst Pasteur has found a characteristic bacillus which he attempted to breed in pure cultures, and which for a long time he considered to be the exciting cause of hydrophobia. As yet the micro-organism of rabies is not known, all attempts at artificial cultivation having been hitherto unsuccessful. The poison of rabies acts like strychnine.

Transference Experiments.—Raynaud, Lannelongue, Pasteur and others have transferred the disease to rabbits by inoculating them with the saliva of persons affected with rabies. Pasteur obtained from the blood of these rabbits a micro-organism which he cultivated in veal broth; it was a bacillus somewhat contracted in the centre, and surrounded by a gelatinous substance. Pasteur at first believed, as we have said, that he had found in this bacillus the excitant of rabies; but he then produced the same disease by inoculating healthy human saliva, and he found the same micro-organisms in the inoculated rabbits. Vulpian and Fränkel obtained the same results by inoculating rabbits with normal saliva. Brigidi and Bianchi found in the

saliva, and particularly in the blood of three individuals with rabies, before and after death, micrococci occurring singly or in pairs (diplococci). Only one of the attempts at inoculation in a rabbit was successful. Making use of Pasteur's method, brain substance was used for inoculation in this case. A portion of the brain substance taken from a child which had just died of rabies was placed in a wound in a rabbit's brain which had been exposed through a small opening in the skull and dura. The wound healed without reaction; the rabies began after the lapse of thirty-two days, and in two days the animal was dead. The autopsy revealed complete cicatrisation at the point of operation, intact meninges, intact brain and spinal cord, and no suppuration. In the brain, spinal cord and blood numerous micrococci were found. An attempt at inoculation with the brain matter of this animal gave no results.

Contrary to the views hitherto held upon the subject, L. Gibier has successfully inoculated birds (chickens) with hydrophobia, and from these he again transmitted the disease to rats by inoculation, which then died with the characteristic symptoms of rabies. Sometimes the inoculated birds withstood the disease. Microscopical examination of the brain of the diseased animals always revealed the presence of the above-described micrococcus of Gibier.

Transmission of rabies from the maternal animal to the fœtus *in utero* has been observed by Perroncito and Carita in rabbits and guinea-pigs.

Strengthening and Attenuation of the Rabies Poison according to Pasteur.—It is well known that Pasteur has artificially strengthened and weakened the virulence of the poison of hydrophobia. By continued transference of the poison in rabbits Pasteur obtained a very pure rabies poison which is constant in its effects. The fresh spinal cord and the medullary portion of the brain of such animals contain the strongest virus. If portions of the spinal cord and brain are dried, the virulence gradually diminishes proportionately to the length of time that the drying is continued. Pasteur has been able, by means of systematic inoculations with rabies poison of increasing virulence, to make dogs immune from the bite of mad dogs and from the artificially transferred rabies poison in its most potent form. In conjunction with these experiments on animals, Pasteur undertook, for therapeutic purposes, protective inoculation in individuals who had been bitten by dogs presumably mad (see pages 401–403, Treatment of Rabies). According to Tizzoni and Schwarz, the immunising substance, as in tetanus and diphtheria, is only found in the blood serum of the inoculated animals; it behaves like globuline, and probably belongs to the enzymes. Therefore they recommend that, as in tetanus and diphtheria, the blood serum of animals which have been rendered immune from rabies by inoculation should also be employed in man for prophylactic and curative purposes.

Action of the Rabies Poison.—The action of the still unknown rabies poison is probably similar to that of the tetanus bacillus. We saw in the chapter on tetanus, which is so closely related to rabies, that the number of the bacilli in the system capable of demonstration is very small, and that the tetanus bacilli are destructive not by their numbers but by the formation of the poisonous products of their meta-

bolism (toxine). The poison of rabies acts, as we have stated, similarly to strychnine.

Rabies in the Dog.—The symptomatology of rabies in the dog is briefly as follows: A stage of incubation precedes the disease, and lasts generally three to five weeks, seldom less or more. The longest duration of the incubation stage, according to Bollinger, is eight months. During the incubation the wound from the bite usually heals very rapidly, without any particular inflammatory manifestations. In dogs, two forms of rabies are distinguished—the raging madness, or rabies, and the still rabies. The symptoms of rabies vary in other respects, according to the race, sex, the state of nutrition, etc., of the animal. The raging madness usually begins with a stage of melancholia, which is characterised by great irritability of the animal, a peculiar restlessness, loss of appetite, dysphagia, and nausea. The dog shows a remarkable preference for all sorts of indigestible things, such as hair, earth, straw, dung, etc. The danger for man is the greatest during this stage, and is so much the more so since the first manifestations are often very insignificant. The initial stage, according to Bollinger, lasts one half to two to three days; then follows the stage of real madness—the irritation or maniacal stage—lasting three to four days. The characteristic manifestations of this stage, which only occur in paroxysms, are the change in the disposition, the continued loss of appetite, a peculiar change in the voice, an impulse to escape and run about, disturbances of consciousness, a marked passion for biting, and a rapidly increasing emaciation. A noticeable aversion to water is lacking, according to Bollinger, and only in exceptional instances does spasm occur in the muscles of deglutition. In the last or paralytic stage there is a constantly increasing weakness. The entire picture presented by the bristling animal is frightful to look at. The voice becomes constantly hoarser, the dyspnœa increases, and death generally occurs on the third, fifth, or sixth day, occasionally with partial or general convulsions. The termination, according to Bollinger, is always fatal; recovery has not yet been observed.

The quiet or melancholic form of rabies, which, according to Bollinger, makes up about fifteen to twenty per cent. of the total number of cases of madness, runs a more rapid course, as there is no maniacal stage. In the first stage the manifestations are the same as in the wild variety; then there soon follows a paralysis of the lower jaw, the mouth remains wide open, the voice becomes hoarse, disturbances of consciousness, rapid emaciation, and paralysis of the hind quarters follow, with death in two to three days.

The results of the autopsy reveal little which is positive. The most important changes, according to Bollinger, are a dark, thick condition of the blood, œdema of the brain, more or less pronounced catarrhal changes in all the mucous membranes, particularly in the respiratory and digestive tracts, frequently combined with hyperæmia and ecchymoses, hyperæmia and cyanosis of the parenchyma of various organs, and a high grade of emaciation. In the stomach and intestine there are usually found, instead of the normal food stuffs, indigestible foreign bodies of various kinds.

Hydrophobia in Man.—In man, rabies occurs by far the most frequently as the result of the bite of a mad dog (ninety per cent.), less

often of cats (four per cent.), wolves (four per cent.), and foxes (two per cent.), and it always terminates fatally. Children, especially, often fall victims to the disease. According to the French statistics, one third to one fourth of all the cases of the disease occur in children under fifteen years of age (Ollivier). The question as to how many of those who are bitten by mad dogs are attacked afterwards by the disease, has received very diverse answers. Bollinger is right in maintaining that the percentage of those attacked by the disease depends upon whether one only takes into account the bites of really mad animals, or also of those which are supposed to be mad; and finally upon whether, and when, energetic prophylactic treatment of the wound made by the bite is adopted. This explains the discrepancies in the records, some of which state that a half, others a third, or even not more than five per cent., of those who are bitten become affected with hydrophobia. The cases of death from rabies in animals and in man have diminished remarkably in states such as Prussia, where there are stringent laws levied against all dogs found running about loose, or those thought to have hydrophobia, and where the muzzling of dogs is compulsory; indeed, in such states, as Flügge has stated, rabies in man has as good as entirely disappeared. As yet no undisputed case has been observed of the transmission of rabies from man to man.

In man, also, rabies is marked by a stage of incubation, generally of eighteen to sixty days, and occasionally of three to six months. An incubation of less than fourteen days is rare, and only in exceptional instances are there incubations lasting from six to twelve months. After the termination of the incubation period, during which the person who has been bitten feels perfectly well, and the wound has healed, usually with exceptional rapidity, the rabies begins with psychical disturbances (a melancholic frame of mind, excitability, restlessness, loss of sleep), loss of appetite, and occasionally, even at this stage, an antipathy towards liquids. The local manifestations at the point of the bite, which has generally healed, are not constant; occasionally there is observed an inflammatory swelling of the cicatrix, or the patient complains of pain, burning or itching. Fever is usually not present. The prodromal stage lasts, for the most part, about twenty-four hours, rarely longer. The first symptom of true hydrophobia in man is a spasm of the pharynx resulting in an inability to swallow. There now occur, in the form of paroxysms, severe respiratory and pharyngeal spasms caused by any kind of irritation, and especially by the sight of liquids—hence the name "hydrophobia." At the same time there are observed reflex spasms, for the most part general clonic spasms, less often tetanic. There is also a characteristic increased reflex

excitability of the nerves of special sense; the patients suffer from a perverted sense of smell; they are over-sensitive to any noise, any draught of air, etc. They are usually afflicted with a nameless dread, which does not allow them to get any rest; the salivary secretion is increased; the mind remains, in the intervals, for the most part clear, but from time to time there are maniacal seizures, partly as a result of the terrible dread and the oppression in the chest due to the feeling of suffocation, and partly as a result of the attempts of others to restrain them. The pulse, which is at the outset full, gradually becomes weaker and more frequent, particularly after the paroxysms, when it reaches 120 to 160 or more. The temperature is generally only slightly elevated—38° to 38·5° C. (100·4° to 101·3° F.)—seldom reaching 40° C. (104° F.) or more. After the above-described manifestations of the second stage have lasted for one to two to three days, there occurs, with an abatement of the spasms and the difficulty in breathing and swallowing, a general exhaustion; death then follows within the next few hours, with convulsions, or even perfectly quietly, or less often during a recurrence of one of the attacks of spasm. The consciousness is usually unclouded up to the last.

The duration of rabies in man is, in the majority of cases, two to four days, rarely more or less; the termination, as in animals, is regularly fatal.

Result of Autopsy.—The results of the autopsy in man are similar to what we have briefly described for rabies in animals—that is, the autopsy shows practically no characteristic changes. Schaffer called attention to an acute diffuse myelitis of the central nervous system in both the grey and the white matter, with marked degeneration of the nerve fibres and ganglia. Popoff often found in the nerve fibres of the central nervous system a very high grade of hypertrophy of the axis cylinder and an atrophic condition of the nerve cells, with conspicuous pigmentation. Popoff saw these changes chiefly in the motor centres. At all events, there is a pronounced parenchymatous myelitis, which affects principally the nuclei of the motor nerves (Charcot, Leyden, Erb).

Diagnosis.—In the diagnosis of rabies in man, the pharyngeal and respiratory spasms, the increased reflex excitability, and the paroxysmal nature of the manifestations of the disease are characteristic. Rabies can only be confused with tetanus of the head, the so-called *tetanus hydrophobicus*, which occurs in conjunction with wounds in the region supplied by the cranial nerves (§ 73), as in this also there are pharyngeal spasms. In such cases the patient's statements may point to the correct diagnosis. Tetanus, for the most part, occurs between the third

to the eighth to the tenth day after the injury, and hydrophobia in the fourth to the seventh week after the reception of a bite from a rabid animal.

Prognosis.—The prognosis of rabies in man is regularly fatal. No certain cases of recovery from true hydrophobia have been observed.

Treatment of Rabies in Man.—Prophylaxis is of the first importance in the treatment. Strictly enforced police laws against allowing dogs to run about loose without their masters, also a high dog-tax, and laws compelling the use of muzzles, are of the greatest importance in lessening the occurrence and the spread of hydrophobia. As we mentioned before, it has been possible in this way to very materially diminish the frequency of the disease.

If a person is bitten by a mad dog, or by one supposed to be mad, the poison at the point of infection—that is, in the wound—must be destroyed as soon and as energetically as possible by careful disinfection with a one-fifth-per-cent. solution of bichloride of mercury or a five-per-cent. solution of carbolic acid, followed by energetic cauterisation with the red-hot iron, the Paquelin, or with chemical caustics (caustic potash, sulphuric and nitric acids). It is also a very good plan to immediately suck out the fresh wound. Excision of the wound or cicatrix, with subsequent cauterisation, may be efficacious, even though done several days or weeks after the injury was received.

Pasteur's Protective Inoculation.—It is well known that Pasteur has undertaken protective inoculations upon people who have been bitten by mad dogs, after he had made the discovery, as stated above, that dogs become gradually unsusceptible to hydrophobia when inoculated with rabies poison the virulence of which is gradually increased. Bordoni-Uffreduzzi has successfully practised Pasteur's preventive inoculation on dogs and on one horse. Tizzoni and Schwarz recommend the use of blood serum taken from animals (rabbits, dogs) rendered artificially immune, for prophylactic and curative purposes in man, since the immunising or curative substance is, as in tetanus, chiefly found in the blood serum.

Technique of Pasteur's Protective Inoculation.—Pasteur's manner of performing protective inoculation is as follows : A suitable amount of the dried spinal cord of an animal which has had rabies is pulverised with sterilised instruments, and to it is added sterilised veal bouillon. Lymph is thus obtained of varying virulence, according to the relative amounts of the constituents and the length of time that the cord has been dried. The material for inoculation is now injected with a hypodermic needle beneath the skin of the abdomen a little below the ribs, three fourths of a cubic centimetre being used for full-grown men and a little less for women, and half a cubic centimetre for children. Pasteur usually begins with a spinal cord

which has been dried for fourteen days, then on the following day an injection is made of one dried for thirteen days, etc., until for the tenth inoculation a spinal cord is employed which has only been dried five days ; the patients are then discharged. Sometimes, especially in bad cases—for example, in Russians bitten by mad wolves—according to Uffelmann's report, inoculations are made two to three times a day with rabies poison of increasing virulence. In this manner Pasteur has inoculated a great number of people who had presumably been bitten by mad dogs ; of these people some died of rabies a short time after the treatment, and others later, and it is not impossible that death from hydrophobia may have occurred in some of the cases in consequence of the inoculation. But in a great number of cases the protective inoculation may have given the wished-for result. At all events, Pasteur's experiments are of the greatest scientific interest; but we must acknowledge, with Koch and Flügge, that Pasteur's protective inoculation for man has been used, for practical purposes, much too soon. A more thorough scientific investigation of the method should have been made before it was put to practical use. According to the results hitherto recorded, the success of protective inoculation is uncertain ; and, on the other hand, there is the danger that people who would otherwise have remained healthy may, in consequence of the inoculation, become infected with rabies and die.

Bordoni-Uffreduzzi has likewise employed Pasteur's method of treatment with the best success, and in his statistics during the years 1886–'88 he reports : Two hundred and forty-one persons were bitten by animals which were experimentally proved to have rabies ; in the case of two hundred and forty-five more, treated by Pasteur's method, the hydrophobia of the animals which bit them was rendered certain by physicians' certificates or by clinical observation ; in forty-five persons the diagnosis of rabies was doubtful. Only six of the first group died ; of the second, four ; of the third, none ; and consequently the mortality of the whole list was 1.88 per cent.

When the disease has once broken out, usually no treatment is of avail. We are then forced to limit ourselves to easing the great sufferings of the patient by symptomatic treatment. First of all, and as soon as possible, large doses of curare should be injected subcutaneously.

Pensoldt, in one case occurring in an eleven-year-old boy, employed without success very large doses of curare, injecting on an average 0·01 to 0·02 gramme every half hour, and in the course of one to two and a half hours the full fatal amount of curare was administered. Curare is very valuable in all cases as a symptomatic remedy for modifying the pharyngeal and respiratory spasms, but it does not possess an actual curative effect upon the disease. Remedies like chloral and chloroform are indispensable. For the severe convulsive and maniacal seizures of the patient the continuous administration of chloroform by inhalation is probably the best treatment.

Recently various remedies have been recommended for rabies. For example, Kartschewskji speaks well of the internal use of cantharides

powder (0·06 gramme *pro die*) for a week, and at the same time the application of emplastrum cantharidum to the wound made by the bite. According to the experiments of De Blasi and Russo Travali, the poison of rabies has little power of resistance against the ordinary antiseptics and caustics, and they recommend creolin and succus citri. The latter, as is well known, has a great reputation as a popular remedy.

§ 81. **Poisoning by Insects, Snakes, Etc.**—From the bites of certain insects and snakes, poisoning, sometimes mild and sometimes severe, may result, the nature of which we do not as yet fully understand. Amongst the injuries caused by the stings of insects belong the bites of gnats, fleas, bugs, etc., after which, as a result of the introduction of some irritating substance, there ensue local inflammatory manifestations in the form of redness and wheals, with itching and burning. Severer inflammation follows the wound inflicted by the sting which is situated in the posterior end of the bodies of bees and wasps. Their sting involves a decided poisoning of the wound, which occasionally presents itself as a very extensive, painful inflammation, with redness and swelling, and not rarely there may even be alarming constitutional symptoms. Many individuals are exceedingly susceptible to the stings of bees and wasps. The local inflammatory manifestations usually subside very soon. The constitutional symptoms which now and then occur—for instance, after the direct injury of a small cutaneous vein or a lymphatic vessel—consist sometimes in a peculiar state of collapse; the skin is cool, and covered with a clammy sweat, the pulse is small and rapid, and occasionally a condition of coma is observed. These threatening constitutional symptoms last usually only a few hours, but the patients generally feel remarkably feeble for several days. There are also many examples known of men and animals dying in a short time after being attacked by a swarm of bees or wasps. The nature of the wasp and bee poison is as yet unknown.

Injuries from Tarantulas and Scorpions.—I should also mention injuries produced by the tarantulas and scorpions of southern countries, with the subsequent extensive local inflammations, which never terminate fatally.

The *treatment* of the above-mentioned injuries, particularly the stings of bees, wasps, tarantulas, and scorpions, is best carried out with ammonia and antiphlogistic remedies. As Billroth says, bee-tenders employ scorpion oil as a kind of antidote for bee stings—that is, olive oil in which some scorpions have been kept.

Injuries from Venomous Snakes.—The injuries due to poisonous snakes are relatively rare in our zones as compared with the tropics.

The nature of the snake poison is as yet unknown to us; it is probably a poisonous alkaloid which is contained in the secretion of the poison glands. In Europe there are ordinarily found only three kinds of poisonous snakes—the vipera berus, the vipera redii, and the vipera aspis. These poisonous snakes have two hook-shaped poison teeth, in which the excretory ducts of small glands empty. At the time of the bite the glands empty their poisonous juices into the wound. By drying the secretion from the poison glands of forty asps, Karlinski obtained fifteen grammes of a white amorphous mass, easily soluble in water and alcohol, a twenty-per-cent. aqueous solution of which corresponded in its action to the fresh poison coming from the poison glands of the adder. The bites of the above-mentioned poisonous snakes are in general not very dangerous; according to Billroth, about two die out of a total of sixty bitten.

The *manifestations* after the bite of these poisonous snakes consist in a very painful local inflammation, in coagulation of the blood in the parts immediately adjoining the wound, in thrombosis of the blood-vessels, not infrequently in gangrene, vomiting, high fever, a feeling of anxiety, cramps, great weakness, etc. The affected portion of the body is subsequently often remarkably devoid of sensation. Occasionally death occurs in a relatively short time, preceded by an increasing state of collapse. If a person bitten by a viper redii survives the first two days, the prognosis is in general favourable.

The best treatment for these snake-bites is to immediately suck the wound—a procedure entirely free from danger—then to wash out the wound with bichloride of mercury, carbolic acid, absolute alcohol, etc., and, when possible, to cauterise the wound with some energetic liquid caustic or with the hot iron. To prevent the rapid absorption of the poison, it is a very good plan to employ the popular remedy of tying off the injured portion of the body—an extremity, for instance—as soon as possible, close above the bite. Energetic antiphlogistic measures are adopted for the local inflammation. Finally, the internal and subcutaneous administration of liquor ammonii fortior has been recommended, a hypodermic syringe full (one part liq. ammon. fort. with one to two to three parts water) being used as a subcutaneous injection; internally ten to twelve drops of the same mixture should be given many times each day. Karlinski praises the injection of one per cent. chromic acid and of chlorine water (Lenz) into the wound made by the bite and the surrounding parts. Large doses of alcohol (whiskey) and energetic active motion of the muscles are in great repute amongst the laity.

The most dangerous poisonous serpents are the American rattle-

snakes and the cobra species of Asia and Africa. After injuries inflicted by the bite of these snakes there ensue extremely severe local inflammations which terminate in gangrene. The constitutional manifestations are like those in hydrocyanic-acid poisoning, consisting in a feeling of dread, oppression of the chest, cyanosis, delirium, convulsions, and stupor. Death follows, occasionally in a few hours, with symptoms of collapse; in fact, death not infrequently occurs before any local symptoms make their appearance. It is of practical importance to note that the poison may even have a fatal effect when in a dried condition or in an alcoholic preparation. According to Cohnheim, death from a poisonous snake-bite is in all probability caused essentially by the disintegration of the red blood-corpuscles.

The *treatment* is in general like that for the bite of a vipera berus. Richards and De Lacerda, basing their opinion upon experiments with the poison of the cobra, recommend the subcutaneous injection of a five-per-cent. aqueous solution of permanganate of potassium (eight to twelve grammes of the solution). Immediately after the reception of the bite a ligature should be placed on the proximal side of the wound, the ligature not being removed until several minutes after making the injection. In one case potassium permanganate was injected with success twenty-five minutes after the reception of the bite. The length of time within which a subcutaneous injection of potassium permanganate is attended with success becomes proportionately prolonged when a ligature is applied above the poisoned wound. If the poison has already caused constitutional symptoms, Richards's observations show that the injection of permanganate of potassium has no effect.

§ 82. **The Poisoning of Wounds by Indian Arrow Poison.**—This is perhaps the best place briefly to consider the wound infections produced, for instance, by the poisoned points of arrows used by the Indians. According to W. T. Parker, the arrow-points of the American Indians are poisoned with a devilish cunning, and the process is frequently kept secret. Vegetable poisons, especially curare or urari, or decomposing putrid substances (decomposing meat and blood, for instance, of dead enemies, decomposing liver, etc.), or snake poisons, made, for example, from the crushed heads of serpents, are employed. There is also a partiality for using the liver of an ox, which is pierced with arrows and allowed to decompose in the sun; crushed ants are also added to the mixture. The symptoms of poisoning differ according to whether a vegetable poison like curare, or putrid substances, or animal poisons like those of snakes, or mixed poisons are employed. The action of curare, the real arrow poison of the Indians, is, as is well

known, to paralyse voluntary muscles, except those of the heart and respiration. The cardiac and respiratory activity only succumb after poisoning with very large doses of curare. The American Indians still commonly use the arrow, in addition to firearms, for war and the chase. The point of the war arrow, according to W. T. Parker, is short and broad, and so formed as to enter easily between the ribs of a man. The hunting arrow is the weapon to be most feared. The Indians can shoot this about one hundred metres, and with as great accuracy as the best modern revolver. The arrow penetrates the tissues with great force, and can perforate the stoutest bones. Gutters are made in the shaft to permit the blood to escape from the wound. The point of the arrow is fastened to the shaft in such a manner that when it becomes wet, and consequently when it is in a wound, or when attempts are made at extraction, it easily becomes loosened and remains in the wound. The arrow-points are made of iron, pebbles, bones, glass, wood, etc. The Indians are greatly skilled in removing the points of arrows from wounds in which they have stuck. A counter opening is often made through which, after cutting off the shaft, the arrow-point is withdrawn.

Appendix.

Chronic mycoses: Tuberculosis (scrofula), syphilis, leprosy, actinomycosis.

§ 83. **Tuberculosis.**—Of the chronic infectious diseases of bacterial origin which are of importance for the surgeon, tuberculosis is very prominent. By tuberculosis (from tuberculum, a nodule) we understand an infectious disease due to a rod-shaped micro-organism, the bacillus tuberculosus (Koch), and characterised anatomically by the formation of nodules, the so-called tubercles. On the 24th of March, 1882, Robert Koch announced to the Physiological Society at Berlin that he had found the cause of tuberculosis, and that the disease was alone produced by a single specific bacillus which he had made grow in pure cultures. The sensation created by Koch's discovery was exceedingly great, and his classical experiments in tuberculosis will always excite the profoundest admiration.

We shall here discuss mainly surgical tuberculosis—that is, the tuberculosis coming within the jurisdiction of surgical therapy, and so particularly the very common tuberculosis of the skin, mucous membranes, lymphatic glands, sheaths of tendons, bones and joints, etc. In whatever part of the body the tubercle bacilli develop and multiply, they always give rise to the formation of characteristic tubercles—that is, to cellular nodules devoid of vessels, which, after the lapse of a defi-

nite length of time and in a certain stage in their development, die, usually by a process of cheesy degeneration.

Origin and Structure of the Tubercles.—These tubercles (Fig. 289) originate, according to the very careful investigations of Baumgarten, Cornil, and others, in the following manner: In consequence of the growth of the bacilli in any particular tissue, there occurs, in the first place, a proliferation of the fixed tissue cells, which begins with the process of caryomitosis and leads to the formation of protoplasmic, epithelial-like or epithelioid cells. The tubercles are consequently at first made up essentially of groups of epithelioid cells which lie within the connective-tissue stroma of the original tissue, which has been partly absorbed and partly pushed aside—the so-called reticulum of the tubercle. Some epithelioid cells have one nucleus, others two, while still others are polynuclear—so-called giant cells—in which there are often found a very great number of large oval nuclei. The giant cells probably originate not by the fusion of several epithelioid cells but by the proliferation of the nuclei of a single cell. In spite of the vigorous growth of the fixed-tissue cells (connective-tissue cells; cells of the walls of the vessels, epithelium) no new formation of capillaries takes place within the nodules. After the proliferation of the original tissue cells there occur, sooner or later, inflammatory changes in the vessels of the diseased region which lead to an emigration of the colourless blood-corpuscles, first in the periphery and then later in the centre of the nodules. The nodules, which are at the outset made up of large cells, thus come to be made up more and more of small round cells. If the emigration of leucocytes occurs at a very early stage and masks the growth of the fixed cells, it is possible for the nodules to appear to be made up of small cells from the very beginning. When the grey transparent nodules, which are about the size of millet seeds, have reached the stage of the small-celled tubercles they are no longer capable of further development, and there now occurs a retrograde metamorphosis, the cells perishing by fatty or cheesy degeneration or by

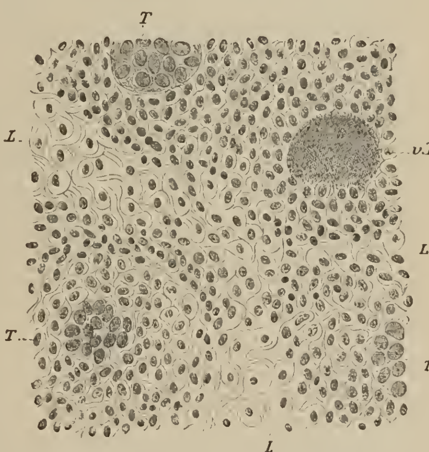


Fig. 289.—Tuberculosis of lymph glands: *T*, tubercle with giant cells in the centre, and large celled tissue between the separate tubercles; *v. T*, cheesy tubercle; *L*, tissue of the lymph-gland, stained with hæmatoxyln. × 200.

coagulation necrosis, and forming homogeneous masses. Frequently the tubercular foci become permeated with lime salts, and finally form mortar-like concretions. The typical death of the tubercle is by caseation or cheesy degeneration (Fig. 289, *v. T.*). The cause of these tubercles—that is, the cause of tuberculosis—is the above-mentioned rod-shaped bacillus discovered by R. Koch (bacillus tuberculosus, Fig. 224, page 258).

Tubercle Bacilli.—The characteristic bacilli present in the nodules are found either in the interior of the cells—for instance, within the giant cells (Fig. 290)—or between the cells; also in the blood of those suffering from general tuberculosis, in the sputum of those with tuberculosis of the respiratory tract, in the urine in genito-urinary tuberculosis, in pus, etc. To Koch alone is due the great credit of having proved, by inoculations with pure cultures of his bacillus, that the bacilli present in tuberculosis are the sole cause of the disease.

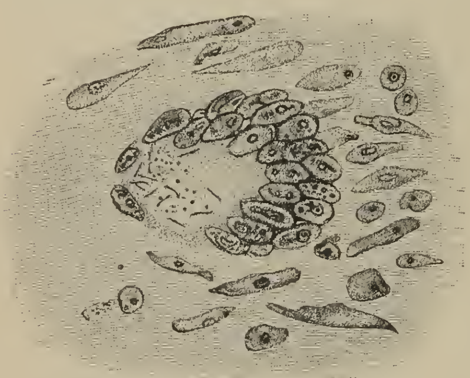


Fig. 290.—Giant cell with tubercle bacilli. × 700 (Koch).

Robert Koch's Tubercle Bacilli.—The tubercle bacilli are fine, generally slightly curved rods from 1·6 to 3·5 μ in length, incapable of spontaneous movement. They usually occur singly, rarely in pairs, and sometimes filaments are seen made up of five to six segments. Whether or not the bacilli form spores has not hitherto been determined. When the bacilli are stained there are occasionally seen bright vacuoles having a regular arrangement, which are suggestive of spores. The bacilli are extremely resistant, probably as a result of their very firm membrane or envelope; hence they do not lose their virulence, though dried for a month, or subjected to high temperatures nearly reaching the boiling-point, or when subjected to decomposition or the acid gastric juice.

The cultivation of the facultative anaërobic, strictly parasitic bacteria outside of the animal body is accompanied with difficulties. They thrive best of all upon the hardened blood serum of sheep, cattle, and calves in the incubation apparatus, at a temperature of 37° to 38° C. (98·6° to 100·4° F.). A tubercle containing bacilli or some similar substance taken from a slightly caseous lymph gland can be used for the seed. Below 29° C. and above 42° C. tubercle bacilli cease to grow. At an incubator temperature of 37° to 38° C., if the culture is very carefully protected from impurities and from becoming mixed with other bacteria, there develop upon the blood serum characteristic

greyish-white, small dry scales or crumbs, which become visible through the microscope within five to six days, but to the naked eye only after the lapse of ten to fifteen days. From the end of the third week on, the appearance is very characteristic. In a test tube the tubercle bacilli thrive exceedingly well upon meat-peptone agar to which has been added three to five per cent. of glycerine (Nocard, Roux). This glycerine agar is at present almost exclusively used for making pure cultures, and is displacing more and more the blood serum which is so difficult to sterilise. When tubercle bacilli are inoculated with the platinum wire upon glycerine agar, the first colonies will be observed along the line where the wire was drawn about fourteen days subsequently. If the culture is allowed to remain in the incubator for one and a half to two weeks longer the typical picture of a tubercle-bacilli culture will be obtained—that is, there will be seen upon the agar an uneven, greyish-white, dry, lustreless mass, which is made up of flakes, nodules, and small scales (Fig. 291). The colonies consist of variously interlacing strings of bacteria clinging together (Fig. 292). Tubercle bacilli also thrive in bouillon to which three to five per cent. of glycerine has been added, and they have even been cultivated upon slices of potato (made alkaline) which were kept from drying by fusing together the open end of the glass tube containing them (Globig, Roux).

Fig. 291.—Linear culture of tubercle bacilli upon glycerine-agar 5 weeks old.

The tubercle bacilli retain their virulence, though cultivated in artificial nutritive media, for a long time. Koch has made pure cultures of these bacilli grow in a test tube for more than nine years, and he has observed only a slight diminution of their virulence. The tubercle bacilli must be kept from the light, as in direct sunlight they perish in a few minutes or hours, according to the thickness of the culture. The dispersed daylight acts more slowly.

Toxine of Tubercle Bacilli.—Koch, Prudden and others have attempted to find in the pure cultures of the tubercle bacillus obtained from man the active principle (toxine) which causes the morbid conditions associated wtih tuberculosis. According to the discoveries of Prudden and Hodenpyl, the poisonous substances are not found, as in many other species of fungi, in the nutritive medium, but they are, analogous to Buchner's bacterial protein, fixed to the bodies of the bacilli in an extremely resistant form. Their sojourn in the living body does not change them for a long time. Complete recovery from tuberculosis is not obtained by the death of the tubercle bacilli, but the tubercular foci containing the dead bacilli must likewise be done away with or the tubercular poison itself rendered harmless.

Thomas Weyl has isolated a highly poisonous substance—toxomucin—from cultures of tubercle bacilli. According to Maffucci, the toxic substance formed by tubercle bacilli only acts after the lapse of a long period

of time, and animals, such as guinea-pigs, inoculated with this poison die of marasmus. Richet and Hericourt have obtained from tubercular cultures a toxine which has a toxic effect upon tubercular rabbits, but none at all upon healthy ones.

Certain metabolic products which are dissolved in the nutritive media, in a glycerine-peptone solution, for instance, have, according to Scholl, a curative effect upon the tubercular process when injected subcutaneously. The tuberculin isolated by Robert Koch is described on page 421.

Staining of Tubercle Bacilli.—Different methods have been recommended for staining tubercle bacilli. The examination of sputum for tubercle bacilli is as follows: A portion of one of the ordinary yellow, tenacious lumps is taken from a mass of sputum, transferred to a cover glass, upon which is then placed a second cover glass, and the material to be examined is pressed between them. The cover glasses are then removed from one another, allowed to dry in the air, and passed three times through a flame. While the cover glass is held by thumb forceps, a drop of carbolised fuchsin is placed upon it, the preparation is held a moment over the flame, and this procedure is repeated several times, fresh staining solution being added if necessary. Then the stain is washed off with distilled water. The parts surrounding the bacteria are decolourised with fifteen to twenty per cent. nitric acid by moving the cover glass back and forth a few moments in the latter until the deep-red preparation becomes greenish blue. Then the dissolved fuchsin is washed away in seventy-per-cent. alcohol, and the preparation is rinsed in distilled water and re-stained with methylene blue, by which everything is coloured blue except the bacilli, which still remain red. After washing in water the preparation can be examined immediately, or it may be dried, and mounted in Canada balsam.

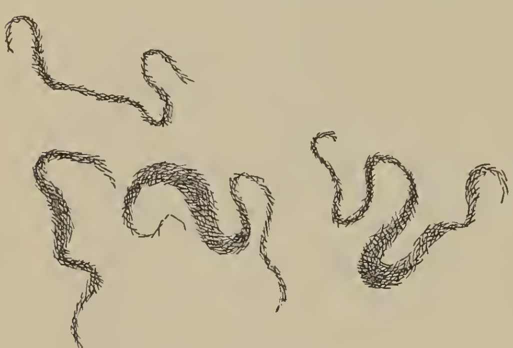


Fig. 292.—Colonies of tubercle bacilli upon coagulated blood-serum.

Of the other methods of staining I should mention particularly B. Fränkel's, which is the best of the remaining ones, and can be quickly carried out (staining with hot carbolised fuchsin, then decolourising and counter-staining in a solution of fifty parts water, thirty parts alcohol, twenty parts nitric acid, and methylene blue to saturation, washing in water). Gram's method is also useful. By the above-mentioned rules a stain can be given to sputum, fæces, pus from a wound, samples of pure cultures, etc. The staining of a section, and consequently of the tubercle bacilli in the tissues, is done in essentially the same manner (for instance, immersion for one hour in carbolised fuchsin, decolourising in dilute [ten-per-cent.] nitric acid for about one half to one minute, washing in seventy-per-cent. alcohol, counter-staining in methylene blue for two to three minutes, dehydrating in absolute

alcohol, clarifying in oil, and mounting in Canada balsam). Ehrlich's aqueous aniline-dye solutions are also much used for sections and cover-glass preparations (at ordinary temperatures the object is immersed for at least twelve hours in Ehrlich's solution [aniline-water, fuchsin, or gentian violet], at higher temperatures for a shorter time, then for a few seconds it is washed in twenty-five-per-cent. nitric acid, and for several minutes in sixty-per-cent. alcohol, then double stained in Bismarck-brown or a methylene-blue solution, depending upon whether it was first stained with violet or fuschin, then washed in sixty-per-cent. alcohol and dehydrated in absolute alcohol, clarified in oil of cedar, and mounted in Canada balsam).

Transmission of Tuberculosis to Animals.—The transmissibility of tuberculosis to animals by inoculation, by intravenous injection, and by allowing them to eat and inhale tuberculous substances had been proved by Klencke, in 1843, before Koch's epoch-making experiments had been made. Villemin (1865–'68) was the first to demonstrate by systematic experiments that tuberculosis can be transmitted from man to animals, and from animal to animal. These experiments were then repeated with positive results, particularly by Chauveau, Cohnheim, Klebs, and others. Then Robert Koch showed that tuberculosis could only be transmitted to animals by inoculation, by intravenous injection, and by inhalation when the material employed contained tubercle bacilli. In the first place, Robert Koch repeated many times successfully the inoculation experiments which had been performed upon guinea-pigs, rabbits, etc., with portions of tubercular tissue (nodules of miliary tuberculosis, tubercular pus, phthisical sputum, fungous matter from joints, lupus, portions of scrofulous glands, nodules of bone tuberculosis). He then employed in a great number of transmission experiments pure cultures of tubercle bacilli, and by inoculating these into the subcutaneous tissue, into the anterior chamber of the eye, and by injecting them into the peritoneal cavity and into the veins, and by causing them to be inhaled, he produced true tuberculosis, with its characteristic bacilli, which could be again and again successfully transmitted to other animals. So Koch has furnished in the most convincing manner the indisputable proof that tuberculosis is caused by specific bacilli. Koch's admirable work will be found in the Mittheilungen des Kaiserlichen Gesundheitsamtes, 1884.

Almost at the very same time that Koch published his work upon the etiology of tuberculosis, Baumgarten, independently of Koch, had likewise found bacilli in the tubercles produced in rabbits by inoculation, but he did not make cultures and inoculations with them.

All animals are not equally susceptible to tubercle bacilli. Guinea-pigs, rabbits, and ruminants have a pronounced predisposition for tuberculosis, while dogs, rats, and white mice are immune from it. It is well known that man shows great variations in susceptibility to the poison of tuberculosis.

Tuberculosis of Cattle.—The tuberculosis of cattle, in which small and large nodules are formed even reaching the size of a walnut or potato, is, according to recent investigations, identical with the tuberculosis of man, and the presence of tubercle bacilli has likewise been demonstrated. Inoculation experiments have also given corresponding results. By the ingestion of meat and milk containing tubercle bacilli from tubercular cows (particularly those with local tubercular disease of the udder), tuberculosis may easily

be caused in man. If boiled, the virulence of infected milk is destroyed ; its poisonous character may be weakened by diluting it with milk which is free from bacteria (Bollinger).

Pseudo-Tuberculosis.—Eberth has described a pseudo-tuberculosis of guinea-pigs. Changes simulating tuberculosis are found particularly in the abdominal organs, especially in the liver, and to a less extent in the lungs. Some of the nodules present the appearance of miliary tubercles, others of small abscesses. In the centre of the nodules collections of micrococci are found, and the nodules themselves appear microscopically either as spots of coagulation necrosis, surrounded by a zone of leucocytes, or as collections of pus. The tuberculose zoöglöeique of Malassez and Vignal is probably identical with this pseudo-tuberculosis. Eberth also observed a tubercle-like disease—a pseudo-tuberculosis—in rabbits, and he found the micro-organisms to be small, short rods, double the width of tubercle bacilli and rounded at the ends, forming chains made up of shorter or longer segments, which were either placed side by side or twisted together in groups and collected in thick clusters. Eppinger found a cladothrix form to be the excitant of pseudo-tuberculosis in man.

The Tubercle Bacillus of Birds.—The weakened (attenuated) or virulent tubercle bacillus of birds, cultivated in a liquid of slight nutritive powers, furnishes substances, according to Courmont and Dor, by means of which rabbits can be made immune from the effects of inoculation with the tubercle bacillus of man.

Combination of Tuberculosis with Carcinoma and Syphilis.—In rare cases there has been observed the simultaneous occurrence of carcinoma and tuberculosis in the same portion of the body; for instance, an eruption of tubercles may be found in the neighbourhood of a carcinoma of the stomach or larynx. In such instances the tubercle bacilli have gained access to the surrounding tissues through the carcinomatous ulceration (Zenkel, Hofmokl, and others). The simultaneous occurrence of syphilis and tuberculosis is also interesting ; the syphilitic product, for example, may gradually take on a tubercular character from the lodgement of tubercle bacilli (Eisenberg, Leloir). In consequence of such a mixed tubercular-syphilitic infection, there will be observed corresponding affections—for instance, of the lymphatic glands and skin—which will only partially disappear under antisyphilitic treatment.

Origin of Tuberculosis in Man.—In the first place, individual predisposition, which may be congenital or acquired, is of particular importance in the acquirement of tuberculosis by man. This predisposition is due to general constitutional conditions and to local changes in the tissues, and especially to variations in the metabolism of the tissues exhibited by some individuals, as well as a change in the irritability of the cells. Foremost in this category stands scrofula, a congenital or acquired constitutional disturbance of nutrition. Climatic and other conditions peculiar to certain regions are also of great importance. In many places, such as certain high resorts or regions where lime industries exist, tuberculosis is almost unknown.

The tubercle bacilli or their spores, whose existence is still doubtful, are contained in the atmospheric air, into which they get from the excretions, or the sputum, etc. of animals or man affected with tubercular disease. Tubercle bacilli are found particularly in the dust or the air in which phthisical sputum has opportunity to dry and become dispersed. They are also carried about by flies (Spillmann, Haushalter). To put a prophylactic restraint upon tuberculosis it is advisable first of all to introduce cuspidors into more general use, provided with a solution of bichloride of mercury (Cornet). Healthy people can very easily become infected with tuberculosis by constant contact with unclean phthisical individuals. Tubercle bacilli are taken into the body chiefly by the lungs; they also are taken into the intestine with the food, or they find entrance through an interruption in the continuity of the skin, through fresh wounds, etc. Tuberculosis produced by inoculation into very small wounds or cutaneous abrasions is observed particularly on the hands of physicians, students, nurses, dead-house attendants, washerwomen, etc. According to Baumgarten, Tangl, and others, the bacilli, as the result of their growth and multiplication, always form at the point where they were absorbed, a local tubercular focus of inflammation. They may also gain access to the circulation, and by it be carried into the internal organs, particularly the lymph glands and bones (the marrow). The tubercular affection is, at the outset, always purely local (Baumgarten, Ponfick), but if the poison gets into the general circulation and so is distributed throughout the system, general miliary tuberculosis, or a flooding of the body as it were with bacilli, can take place.

Local tubercular disease originates with preference in the places where the tubercle bacilli easily find lodgement and are not mechanically swept away, as in the lungs, the lymph glands, in the capillaries of the bone marrow which have no walls, in terminal vessels, and especially in blood extravasations. According to Robert Koch, tuberculosis in man originates most frequently in the lungs. It is a matter of importance for the surgeon to know that tuberculosis of the skin and lymph glands can result from scratches, cutaneous eruptions, and ulcers in the skin. Czerny saw two cases which had been inoculated with tuberculosis by skin transplantation. Embolic tuberculosis of different organs, particularly the bones and joints, frequently originates from tubercular bronchial glands.

Extension of Tubercular Inflammation.—The extension of the tubercular inflammation, which, as we have said, is at the outset purely local, is dependent upon the multiplication of the bacilli. The extension either proceeds steadily by contiguity, or the wandering cells carry the bacilli

into the adjoining parts and there form new foci, which either remain isolated or gradually coalesce with the primary focus. By the entrance of living bacilli into the circulation (blood, lymph) the tubercular inflammation may be distributed throughout the entire body. We observe an extension of the tubercular inflammation by contiguity when, for example, a tubercular inflammation of the bone marrow breaks through the bone and infects a neighbouring joint. In a similar manner the large serous cavities become diseased, usually by direct extension of the tubercular inflammation from one of the organs that form their walls (Weigert). Thus tubercular pleurisy originates, in the majority of instances, from a small pulmonary focus extending to the pleura, or from tubercular disease of the vertebræ, ribs, or lymph glands. Tuberculosis of the peritoneum is most frequently observed in conjunction with a tuberculosis of the intestine, the female organs of generation, etc. Deposition of the poison directly from the blood into the serous cavities seldom takes place. Occasionally the extension of the tuberculosis can be traced along the lymph channels. In such cases there will be observed a corresponding formation of nodules in the course of the lymphatic vessels. From the lymph channels the poison passes into the lymph glands, then through the thoracic duct into the blood-vessels; or it may break into a vein directly, and in such cases cause a general distribution of the bacilli all through the system, so that nodules occur everywhere (general miliary tuberculosis), and then death usually follows in a short time.

Tubercular Systemic Poisoning.—In fourteen cases of general miliary tuberculosis, Weigert, by carefully examining the veins, was able thirteen times to demonstrate the place where the poison broke through into the veins, or into the thoracic duct, in the form of tubercular thrombi. Not infrequently there is an extensive formation of tubercles in the walls of the vessels. The bacilli occasionally lodge in the intima of the thoracic duct itself. In such cases there is observed a cheesy ulceration of the intima of the duct (Ponfick).

Demonstration of Tubercle Bacilli.—The demonstration of the tubercle bacilli is, as we have remarked, of the greatest importance for diagnostic purposes, particularly when found in the blood in general tuberculosis, in the sputum in tuberculosis of the respiratory tract, in the evacuations from the bowel in intestinal tuberculosis, in the urine in genito-urinary tuberculosis, and in the pus in tubercular disease of bones, joints, and soft parts. The bacilli can be most easily demonstrated in the sputum when they find a medium favourable for their nutrition, and can keep on multiplying secondarily. According to Robert Koch, the bacilli are particularly apt to be found where the tubercular process is in its inception, the cheesy, suppurating products, as a general rule, containing but few bacilli. Very often the tu-

bercle bacilli cannot be demonstrated in tubercular pus; nevertheless guinea-pigs inoculated with this pus will die of tuberculosis (Tavel). The giant cells, in a process which has lasted a long time, will contain, for the most part, only a few bacilli.

Termination of the Tubercular Inflammation.—Wherever they may occur, both the nodules and the diffuse tubercular infiltration disintegrate and undergo cheesy degeneration. In this way, particularly in the skin and mucous membranes, tubercular ulcers are formed with a cheesy or caseous base after the inflammatory processes have broken through externally. In other cases, particularly in tuberculosis of the bones and joints, extensive suppuration occurs. The pus in the latter process has characteristic properties; it is usually thin, and contains cheesy masses. Occasionally, as in tubercular inflammation of the vertebræ, extensive abscesses develop, which gradually sink downwards along the connective-tissue spaces. These are called congestion or cold abscesses (see Tuberculosis of Bone). In the bones and joints the disturbances excited by the tuberculosis, as we shall see later on, are very considerable.

The tubercular suppuration is mainly due to the tubercle bacilli, though in many cases there is a mixed infection with pus cocci—the staphylococcus and streptococcus (Garré, Tavel).

A reactive inflammation usually takes place around the tubercular focus, encapsulating the latter, the organism trying in this way to protect itself from further infection. The single foci of tubercular inflammation may entirely heal, and they do this the more readily the smaller they are and the earlier and more completely they are removed by operative measures. Spontaneous healing of tuberculosis is due to a reactive inflammation in the neighbourhood of the tubercular inflammation. The cheesy masses become absorbed or encrusted with the salts of lime, the bacilli gradually die, and firm connective tissue takes the place of the tubercular material. But there is always the danger that the tubercular inflammation may break out afresh as long as bacilli capable of development remain enclosed in the original focus of infection. The bacilli, or rather their spores, appear to have great powers of resistance, which explains why tubercular inflammation recurs with such extraordinary frequency. The greater the number of the foci of disease, so much the more improbable is the recovery. All too often the latter is only apparent or temporary, and then suddenly the disease appears afresh. Every individual who has shown his susceptibility to the poison of tuberculosis by having had one attack of the disease is always in danger of a new outbreak.

Inheritance of Tuberculosis.—An important question for the physician is whether tuberculosis can be inherited—that is, whether the tubercle bacillus

is transmitted from the parents to the fœtus, either at the time of conception or during its intra-uterine life.

Transmission of the Tubercle Bacillus from the Mother to the Fœtus.—Congenital tuberculosis in man has not yet been observed with certainty, as far as I know, and consequently there is a tendency not to admit the possibility of the inheritance of the poison of tubercular disease as of other hereditary infectious diseases. But it is generally accepted that the disposition or the tendency to tuberculosis is inherited ; that is, there are transmitted certain peculiarities of the organism—for instance, a peculiar quality of the circulatory liquids, a certain irritability of the cells, etc.—in consequence of which the organism under consideration forms a particularly favourable soil for the tubercle bacillus. Recent experiments and clinical observations upon animals prove, however, the actual occurrence of a congenital tuberculosis in animals. Johne, Hertvig and Csokor found tubercle bacilli in the fœtus of cattle. Koubassoff infected pregnant guinea-pigs with tubercle bacilli ; both the mother and the fœtus became tubercular, and tubercle bacilli were found in each. Landouzy and Martin have also performed experiments which speak for the occurrence of congenital tuberculosis, and Weigert found tubercle bacilli in the spermatozoa of tubercular men. Hence fœtal tuberculosis might originate in man, particularly if there already existed tuberculosis of the genito-urinary apparatus, and if bacilli were present in the blood of the father. It is well known that children of tubercular parents easily contract tuberculosis after birth, and hitherto it has been believed that tuberculosis always originates after birth, because the children in question inherit a predisposition for it and are exposed to a marked extent to infection by contact with their parents. I have no doubt that some cases of tuberculosis apparently originating after birth have already begun *in utero*, and consequently are of congenital origin. This has been recently confirmed by observations made by Birch-Hirschfeld. He demonstrated that the tubercle bacillus has the power of passing through the walls of the vessels from the maternal into the fœtal circulation. He had one case of a twenty-three-year-old woman who had died of miliary tuberculosis in the seventh month of pregnancy. In the placenta there were found, in the intervillous spaces and in the interior of the vessels of the villi, many tubercle bacilli ; they were also found in the liver of the fœtus. Inoculations made with portions of the fœtal organs produced tuberculosis in guinea-pigs. Birch-Hirschfeld still holds to the general opinion that under normal conditions the placenta is impervious for finely divided foreign bodies or micro-organisms, but by pathological processes, or rather by the lodgement of micro-organisms, this filter is made pervious. The bacilli, as it were, grow into the fœtal portion of the placenta in the same way that the anthrax bacilli enter the pulmonary vessels after the inhalation of anthrax spores which Buchner demonstrated experimentally.

Brief Review of Tubercular Disease in the Various Tissues and Organs as far as it concerns the Surgeon.—Concerning the clinical course of tubercular disease in the various organs and tissues as far as it concerns the surgeon, the following brief statement will suffice :

Tuberculosis of the Skin and Subcutaneous Cellular Tissue.—Tubercu-

losis of the external cutaneous covering and of the cellular tissue is of frequent occurrence. The so-called lupus (§ 93, Chronic Inflammations of the Skin) is a special form of tuberculosis of the skin. Lupus occurs alone, or it may be a part of a tubercular constitutional affection. Other tubercular ulcerations of the skin occur, particularly in children and young individuals, either primary or secondary, for instance, to tubercular abscesses of the lymph glands and tubercular bone and joint disease. These tubercular ulcerations of the skin usually yield readily to surgical treatment.

The so-called anatomical tubercle, verruca necrogenica, described in § 76, is occasionally, though not always, a true tuberculosis of the skin.

Primary tuberculosis of the panniculus adiposus, particularly in young children, takes the form of firm, flat, subcutaneous nodes, which gradually extend, coalesce, and break through externally after the skin has necrosed. In other cases they may evince a preference to grow into the deeper parts beneath the more or less uninjured skin.

Primary tuberculosis and primary tubercular abscesses of the deep intermuscular spaces and connective tissue in the neighbourhood of bones and joints are very rare. Tuberculosis in these regions is usually secondary to tubercular disease of the bones, joints, and lymph glands. In this category should be classed the congestion abscesses—that is, the so-called cold abscesses following tubercular disease of the bones or the joints, particularly those of the vertebral column.

Tubercular abscesses are very frequently observed. They are usually enclosed by a characteristic greyish or yellowish-grey membrane—the so-called abscess membrane—containing miliary tubercles. This membrane can be easily loosened or scratched off from the healthy adjoining parts. Only in rare instances is there seen a diffuse spreading of the tubercular inflammation into the muscular tissue. The above-mentioned abscess membrane is only observed in tuberculosis, and is consequently of diagnostic importance. It is lacking in syphilis, in which, in general, there is more frequently observed, in contradistinction to tuberculosis, a diffuse cheesy degeneration of the muscles, for instance.

Tuberculosis of Mucous Membrane—The Tongue.—Amongst tubercular affections of the exposed mucous membranes there is observed a tuberculosis of the tongue which sometimes takes the form of a partly torpid, partly fungous ulceration, and at others of a deep-seated node with central softening. The tubercular ulcer of the tongue, with an indurated area surrounding it, may sometimes be mistaken for cancer, and tubercular nodes have a similarity to syphilitic gummata, but

their local manifestations and the whole clinical course will, in the majority of cases, assure the eorreet diagnosis. In two eases Volkmann saw the entire superficial surface of the tongue eovered with tubereular ulcers, varying in size from that of a pin-head to that of a pea, and between them miliary tubereles were everywhere visible. The great majority of patients operated upon for tubereulosis of the tongue subsequently die of pulmonary tuberculosis; but still some complete recoveries have been reeorded even in individuals strongly predisposed by heredity.

Tuberculosis of the Pharynx and Palate oceurs mainly in tubercular ehildren at the age of puberty and soon after, in the form of ulcers the size of a pea and larger, having a tendeney to eoalesce, and located on the palatine arehes, the posterior wall of the pharynx, and the posterior surfaee of the velum palati. Between the uleers there do not often fail to be miliary nodules, whieh are visible when the illumination is sufficient. Tubereulosis of the pharynx and palate is very apt to be eonfused with syphilis. In the differential diagnosis it is to be noted that syphilis produees more loss of substanee, while tuberculosis is more apt to give rise to extensive uleerating surfaees which have a tendeney to shrink and contraet. In this condition permanent recoveries have also undoubtedly been obtained, but the majority of the patients die of pulmonary tubereulosis.

Nose.—Tuberculosis of the nasal mueous membrane (ozæna tubercularis) oeeurs in the form of a primary tubereular uleeration of the mueous membrane, or seeondary to primary tuberculosis of the bones, partieularly the upper jaw.

Lips.—Severe tubereular ulcerations oceasionally make their appearance upon the lips.

Rectum.—Some fistulæ of the rectum are, as the aneient physicians well knew, tubercular in eharacter. The tubercular reetal fistula is eharacterised by a tendeney to the formation of fungous granulations, by an extensive lifting up of the mueous membrane from the underlying parts, undermining of the skin, and by the formation of abseesses with sinuses. The prognosis of tubereular rectal fistula is very unfavourable.

Intestine.—Tubereular perityphlitis occurs after perforation of a tubercular intestinal ulcer. It gives rise to large tubercular abseesses, and yet patients who have them are often otherwise entirely well.

Genito-urinary Tuberculosis.—It has been my experience to find that tuberculosis of the genito-urinary apparatus runs a partieularly unfavourable course, sometimes with great rapidity. Tuberculosis of the testicle and epididymis—originating either primarily or secondarily to

tuberculosis of the vas deferens or the genito-urinary apparatus—usually occurs in young or middle-aged men, and even old men are not exempt. In general it is best, as soon as possible, to remove the tubercular focus in order to prevent the process from involving the other testicle or the spermatic cord, prostate, and bladder. Tuberculosis of the spermatic cord is characterised by an even thickening or a nodular swelling in the course of the vas deferens. Tuberculosis of the bladder, urethra, and kidneys is very typical, and belongs to the severest of the tubercular diseases. Tuberculosis of the bladder has hitherto resisted all attempts to cure it. The demonstration at an early period of tubercle bacilli in the urine is of great practical importance. For tuberculosis of the kidney or its pelvis, it is best, at as early a stage as possible, to undertake operative treatment in the form of nephrotomy or nephrectomy (Madelung). I must refer the reader to my text-book of special surgery and to the text-books on gynæcology for tuberculosis of the penis, vagina, and uterus. In rare instances inoculation with tuberculosis may take place on the external genitals as a result of coitus (Kraske, Schmidt). Tuberculosis of the mamma is, according to Billroth, Volkmann, and others, very rare, and its diagnosis is only possible in the later stages. In every case of tuberculosis of the breast the entire mamma, with the corresponding axillary lymphatic glands, should be removed.

Tuberculosis of Bones, Joints, and Tendon Sheaths.—I shall refer to tuberculosis of bones, joints, and tendon sheaths in the paragraphs upon these subjects. It need only be stated here that tuberculosis of bones and joints is very common, and that the true caries of bones and joints—the so-called fungous inflammation of bones and joints—is with few exceptions true tuberculosis. Tuberculosis of bones and joints originates very frequently as a result of a traumatism. The tubercular joint inflammations are, particularly in children, secondary in nature, as they are most frequently due to an extension of the process from the bones. The tuberculosis of bones occurs chiefly as a tubercular osteomyelitis, which very frequently leads to the formation of large cold abscesses. Tuberculosis of the tendon sheaths manifests itself sometimes as a diffuse fungous disease and sometimes in the form of separate nodes.

Lymph Glands.—Tuberculosis of the lymph glands is exceedingly common, particularly in the neck. Areas of characteristic cheesy degeneration and suppurative softening develop either primarily in conjunction with a scrofulous hyperplasia of the glands, or secondary to tuberculosis of the lymph district in question. It is of very great practical importance that this glandular tuberculosis should receive

operative treatment at as early a stage as possible, because, if the poison passes into the circulation, general miliary tuberculosis may readily follow.

Diagnosis.—The diagnosis of tuberculosis is rendered certain when it is possible to demonstrate the presence of tubercle bacilli, when inoculation is successful, and the microscopic examination of the tissues reveals the above-described characteristic structure of the tubercles.

Prognosis of Tuberculosis.—We have already sufficiently outlined the prognosis of tuberculosis. Even in surgical tuberculosis, though radical operative treatment may be adopted, a permanent cure is not so often observed as many enthusiasts believe; but the sooner the tubercular focus is removed, the smaller it is, etc., so much the more ground may we have for expecting a permanent, complete cure. But, as has been said, there is always the danger of a fresh recurrence of the disease even years later. For children, the prognosis, in general, is better than for adults; we often enough see spontaneous recovery take place in them from the most severe bone and joint tuberculosis. But we know, from the statistics of Billroth and others, that individuals who have suffered in their youth from tubercular disease of bone do not usually attain an advanced age.

Treatment of Tuberculosis.—For the treatment, I must refer the reader to the treatment of tuberculosis in the different tissues. Only the following brief summary will be given here: The treatment of surgical tuberculosis, particularly, for instance, of bones and joints, until a few years ago was very largely operative. At present the treatment is taking more of a conservative direction. The operative treatment, which used to be so energetically pursued, is in part, and with the best results, becoming supplanted by a more chemical treatment, and chiefly by the aseptic injection of sterilised ten-per-cent. iodoform oil or iodoform glycerine (P. Bruns). To avoid iodoform intoxication, it is best to sterilise olive oil or glycerine and iodoform separately, by heating them at a temperature of 100° C. in the sterilising apparatus, and then to make with them a ten- to twenty-per-cent. mixture. Iodoform, in fact, appears to have a direct antitubercular action, as proved by the experiments of Baumgarten, Troje, and Tange. Arsenic, carbolic acid, balsam of Peru, lime with phosphoric acid, and oil of cloves (1 to 10 of olive oil), etc. (Buchner, Hueter, etc.), have also been recommended for the treatment of surgical tuberculosis. Landerer recommends the intravenous injection of a cinnamic-acid emulsion, which must be first rendered alkaline according to the following formula: Acid. cinamylici 5·0, ol. amygdal. 10·0, vitelli ovi unius, sol. natr. chlor. (0·7 per cent.) q. s. ut f. emuls., 100·0.

Arsenic has been recommended by Buchner both locally and internally. He believes that this remedy greatly increases the powers of resistance of the body, or rather of the cells. P. Bruns and others have obtained no satisfactory results from the injection of Kolischer's phosphate-of-lime solution (calc. phosphor. neutr. 5·0, aq. dest. 50·0, acid. phosphor. q. s. ad. solut. perfect. filtra, adde acid. phosphor. dil. 0·6, aq. destil. q. s. ad. 100·0, and inject about 10 to 12 to 24 c.cm.). Similar unsatisfactory results were obtained with Kolischer's lime-gauze packing. The gauze is impregnated with the above solution and contains ten times its weight of dilute phosphoric acid.

A. Bier has obtained remarkable success in tuberculosis of the extremities by employing permanent congestive hyperæmia, brought about by the application of a rubber tourniquet on the proximal side of the tubercular disease. This method of treatment was suggested to Bier by the well-known fact that the congested lung is immune from tuberculosis.

Especially iodine, arsenic and lactic acid have been used internally. The treatment of the general condition of the patient is very important, and the course of tuberculosis is influenced very markedly by good food and good air and by a strengthening mode of life thoroughly carried out. It is also a good plan to employ baths, sea bathing, sea voyages, yearly sojourns in southern climates (Egypt, Madeira, Sicily), and to try high health resorts (Davos), etc. For prophylactic reasons, individuals with a predisposition to tubercular disease, or scrofulous patients, should be built up by a tonic treatment and kept from associating with those who actually have the disease.

Treatment of Tuberculosis with Koch's Tuberculin.—The treatment of tuberculosis with Koch's tuberculin, a metabolic product of the tubercle bacilli, is of great scientific interest, and discloses a reformatory prospect for the treatment of chronic, and perhaps also of acute, infectious diseases. It is founded upon the idea of killing the tubercle bacilli or the tubercular focus by the products of their own metabolism. We know, in fact, that bacteria, particularly tubercle bacilli, dig their own grave under certain conditions and after the lapse of a certain length of time. Koch's tuberculin is, according to the statements of the discoverer, a glycerine extract from pure cultures of tubercle bacilli, a brownish-red fluid which contains, in addition to the active principle, a toxalbumen, indifferent colouring matters, salts, and extractives. In animals (guinea-pigs) Koch has obtained very satisfactory results with tuberculin; he has cured tubercular guinea-pigs, and has made others unsusceptible to inoculation with tubercle bacilli. In animals the tubercular foci are cast off in a state of necrosis after the subcutaneous injection of tuberculin.

The observations which have been made upon the use of tuberculin for tuberculosis in man have not been as satisfactory as in guinea-pigs. After

its subcutaneous injection in tubercular individuals there generally occurs within about four to six hours a typical local and constitutional reaction which is best illustrated in tuberculosis of the skin, or lupus. The local histological changes following the injection of tuberculin have been described by many authors. These changes consist in a very active inflammation in the parts surrounding the tubercular focus ; the tubercle itself and the bacilli are not directly attacked. In consequence of the inflammation of the parts surrounding the tubercular focus, the latter may be cast off under suitable conditions, but the typical necrotic destruction of the tubercular focus observed by Koch in animals following the action of the tuberculin does not appear to take place, as a rule, in man. In consequence of this inflammation of the surrounding parts the tubercular focus in lupus, for example, becomes very much swollen, a tubercular joint becomes extremely painful, etc. The constitutional effect of tuberculin observed even in healthy people after the administration of very large doses consists in fever and the other well-known febrile constitutional manifestations, which may assume a threatening character. I have frequently observed a rise of temperature to 41° C. (105·8° F.) and higher, and a pulse of 180 to 200. Examination of the blood reveals a temporary acute leucocytosis in which all forms of the white blood-corpuscles are involved. In consequence of this characteristic effect of the tuberculin upon the tubercular focus the remedy has great diagnostic value; only in exceptional cases does the typical reaction fail, as it did, for instance, in a case coming under my observation and subsequently operated upon, in which there was tuberculosis of the testicle and kidney. The typical reaction is occasionally observed even in people seemingly healthy, and then usually means a latent tuberculosis. In the case of an apparently healthy medical student, I observed, after subcutaneous injection of the tuberculin, a marked swelling of the cervical lymphatic glands and high fever ; the cause of this proved to be an anatomical tubercle on the chin, microscopical examination of which after extirpation revealed typical tubercles. If a healthy person reacts to tuberculin, a latent tuberculosis, as said before, may be present.

The *therapeutic results* obtained with tuberculin are not as satisfactory in man as in animals. There are numerous reports upon the tuberculin treatment, particularly of lupus, but permanent cures have only been obtained in very rare instances, and not infrequently the tubercular process has been made worse. Unfortunately the remedy has not always been used in properly selected cases. At present tuberculin is scarcely employed at all. Though Robert Koch may not have discovered the means of curing tuberculosis in man, he is perhaps upon the right road to find a valuable means of assistance in the treatment of tuberculosis, particularly in its early stages. The conditions for rendering it possible to cure surgical tuberculosis are most favourable in those cases where the tuberculin treatment can be properly combined with the operative.

As to the technique of the method, I may say that I employ small doses and not too frequent injections, preferably under the skin of the back. I begin without exception with one milligramme of tuberculin for adults and half a milligramme for children, once or twice a week, gradually increasing the dose to 0·01 to 0·10 gramme. I do not use large doses—for example, 0·20 to 0·50 gramme or more. By the use of small doses once or twice a week the

marked loss of weight, occurring so easily, is prevented, as are also the harmful constitutional symptoms. I have used the tuberculin in a great number of cases of surgical tuberculosis, and in some of them I have observed remarkable improvement, but no cures either in lupus or in any other tuberculosis of soft parts, bones, or joints. I am sorry to say that the improvements were only temporary in their nature, and many cases were even made worse.

The question whether tuberculin may occasionally favour the origin of a general miliary tuberculosis—that is, whether tuberculosis may be made general throughout the body by using the remedy—cannot be answered with certainty, but the possibility of this must be admitted (Virchow).

Klebs's Tuberculocidin.—Klebs has separated from the healing substances in Koch's tuberculin those which are noxious (which produce the necrosis) by precipitation with platinum chloride and phosphortungstic acid and by the addition of alcohol to the residue. The medicinal substance thus obtained, tuberculocidin, which belongs to the peptone group, has been found by Klebs to be of therapeutic value.

Cantharidate of Potassium.—Liebreich recommended the subcutaneous injection of the cantharidate of potassium (up to sixty grammes) ; its action is the same as that of tuberculin. B. Fränkel, Heymann and Landgraf likewise obtained satisfactory results. Martin and Grancher claim to have made rabbits immune from infection with tubercle bacilli of the highest grade of virulence by first inoculating them with tubercle bacilli of weaker but gradually increasing virulence.

In this connection a brief description should be given of the nature and treatment of scrofula.

Scrofula.—By scrofula (from *scrofa*, hog) is understood a constitutional anomaly without anatomical changes that are capable of being positively demonstrated. It is characterised by a striking weakness of the tissues, or rather of the cells, rendering them incapable of withstanding injurious influences from without. Consequently we observe that scrofulous individuals, as a result of the slightest external violence, suffer from inflammations of every description, which may involve the skin, mucous membranes, or lymphatic glands. Scrofulous people, as we have remarked before, possess a pronounced predisposition to tuberculosis—that is, the scrofulous constitutional anomaly, with its local acute and chronic foci of inflammation, is an excellent soil for the tubercle bacillus. The relationship between scrofula and tuberculosis has been very frequently discussed, and since the discovery of the tubercle bacillus the connection between them has become better understood. We now assume that scrofula has nothing to do with true tuberculosis; it is rather a constitutional anomaly by which infection with the bacillus tuberculosus is favoured.

If we have to deal with a cheesy or suppurative lymphadenitis, which is so often observed in scrofula, the decision as to whether we have to deal with tuberculosis or not is made solely upon the demonstration of tubercle bacilli. The same thing holds true of the so-called cold, scrofulous abscess in the soft parts, and the chronic inflammations of bones and soft parts. I am of the

opinion that a pseudo-tuberculosis occurs in scrofulous individuals which is analogous to that observed in animals, which was described by Eberth, Malassez, and Vignal (page 412); it runs a course similar to true tuberculosis, though caused by other micro-organisms (cocci, bacilli), and not by the bacillus tuberculosus Kochii.

The scrofulous constitutional anomaly is either congenital or acquired, as a result of unfavourable external hygienic conditions, a lack of proper nourishment, living in bad surroundings, etc. The most important marks of scrofula consist, in the first place, of a series of manifestations which are usually grouped together under the name of habitus scrofulosus. For convenience we distinguish two forms of scrofula: the irritable and the torpid form. Scrofulous individuals have in general a thin, delicate, transparent skin; they are more apt to be blond than dark, and are of a very excitable temperament (irritable form). In the torpid form of scrofula the skin is more puffed, the subcutaneous fat remarkably well developed, and the abdomen protruding. But all these manifestations are observed without scrofula, and the latter first becomes evident to the eye when local inflammatory manifestations make their appearance, particularly inflammations of the skin, mucous membranes, and glands. Of these, the most constant are: Eczemas of every description which are so common; the catarrh of the throat, bronchi, stomach, and intestines; the pronounced conjunctivitis, blepharoadenitis, and keratitis. The lymph glands are usually swollen and enlarged, with or without simultaneous cheesy degeneration. This is particularly the case with the lymph glands of the neck and submaxillary region, where great masses of enlarged lymph glands may exist. In this way the neck becomes very plump, and merges gradually into the head and trunk, as in pigs. The old-fashioned term of scrofula was derived from this comparison. In this caseous lymphadenitis the transitions to true tuberculosis are very common.

Treatment of Scrofula.—The treatment of scrofula must be directed first and chiefly towards overcoming the existing constitutional anomaly, particularly by the enforcement of proper hygienic rules—that is, by taking care to supply good nourishment, air, and light; by proper exercise in fresh air; by muscular exertion (gymnastics, swimming), etc. A residence at the seaside is particularly to be recommended in scrofula. This does not have a specific effect; it is only an adjuvant in the cure, exciting the appetite of the patient and thus improving his nutrition. The diligent use of salt baths (up to three per cent.) has a good reputation in the treatment of scrofula; they should be employed daily, or, in the case of weak individuals, two to three times a week and for ten to thirty minutes. Kreuznach, Nauheim, Oeynhausen, Reichenhall and Heilbronn have the best reputation amongst the bathing resorts. They are particularly recommended on account of the iodine and bromine contained in the waters. The water is used to drink as well as to bathe in. The administration of cod-liver oil, fifteen to twenty to thirty grammes a day, particularly in winter, is likewise recommended. Cod-liver oil is an easily digestible fat of dietetic importance. Furthermore, scrofulous subjects should be cautiously toughened by degrees, to render them more capable of withstanding the frequent catarrhs of the mucous membranes. Every scrofulous local disease should receive proper treatment. In the matter of prophylaxis, too much emphasis cannot be laid upon the importance of pro-

tecting scrofulous children from contagion with tuberculosis, and from intercourse with those who have the latter disease.

§ 84. **Syphilis** (*Lues*).—By syphilis we understand a chronic infectious disease which, according to recent investigations, is most probably caused, like tuberculosis, by a characteristic fungus. Klebs and Birch-Hirschfeld were the first to discover micro-organisms in syphilis, and to look upon them as the cause of the disease. By transference of the bacilli to apes, Klebs brought about inflammations some of which ran a course similar to the inflammation in syphilis, others to that in tuberculosis. Lustgarten, under Weigert's guidance, by using a special method, succeeded in demonstrating in tissues which had undergone syphilitic changes, and in the secretion from syphilitic ulcers, a particular species of bacillus (Figs. 293, 294) which is morphologically similar to the tubercle bacillus, but differs from it in shape, more frequently occurring in a slightly curved form, with knob-shaped enlargements at its ends. It also differs in its micro-chemical behaviour. While the tubercle and lepra bacilli, which are also brought to view by Lustgarten's method, are not decolourised by hydrochloric or nitric acids (or only after being subjected to them for a long time), the syphilis bacilli rapidly part with their stain under the influence of these acids. The syphilis bacteria, as yet, are not distinguished by any other absolutely characteristic staining reaction.

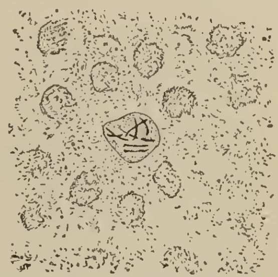


Fig. 293.—Wandering cells with syphilis bacilli, × 1,050 (Lustgarten).

Fig. 294.—Dry preparation of pus taken from a syphilitic sclerosis with syphilis bacilli, × 1,050 (Lustgarten).

The syphilis bacilli are stained by Lustgarten as follows: The thinnest possible sections are treated with aniline-gentian violet for twelve to twenty-four hours, at the ordinary room temperature, then for two hours longer at a temperature of 40° C. in the incubator, washed in absolute alcohol for several minutes, then for about ten seconds in a one-and-a-half-per-cent. solution of permanganate of potassium and for one to two seconds in an aqueous solution of sulphuric acid, and then washed in distilled water. The latter three steps should be repeated many times until the section appears completely colourless, then it is treated with alcohol, oil of cloves, and xylol-Canada balsam. Cover-glass preparations are treated in a similar way, except that, after staining in gentian violet, distilled water is used instead of absolute alcohol,

and the separate steps in the process follow one another more rapidly. Lustgarten never found the bacilli free in the tissues, but always either singly or in groups of from two to eight individuals in large oval or polygonal cells, and chiefly in the wandering cells (Fig. 293). The bacilli are usually to be found only in small numbers, and they are most frequently capable of demonstration in the cover-glass preparations (Fig. 294), rarely in the sections. Doutrelepont, Schütz and others have likewise proved the presence of Lustgarten's bacilli in syphilitic tissues and secretions, but they have not found them in every case. De Giacomi stains the preparations in Ehrlich's aniline-water-fuchsin solution, and then treats them with a chloride-of-iron solution.

The significance of Lustgarten's bacilli has been rendered somewhat doubtful by Alvarez, Tavel, Matterstock, and others. These authors have found in the præputial smegma, and in the secretion between the labia majora and minora and about the anus, bacilli having the same appearance and the same staining reaction as Lustgarten's syphilis bacilli. This fact has been confirmed in every respect by Doutrelepont, Markus, and many others. But the circumstance that the syphilis bacilli are present in syphilitic tissue where there can be no smegma bacilli has the greatest significance as regards their specific importance. At all events, the etiological importance of Lustgarten's bacilli must be tested by further investigation, and the question must remain unsettled as long as it continues to be impossible to artificially cultivate the syphilis bacteria and to inoculate them successfully upon susceptible animals. Doutrelepont believes that Lustgarten's bacilli really bear some sort of relationship to syphilis, while other authorities hold the contrary view. Weigert also believes in the specific significance of Lustgarten's syphilis bacilli. Bäumler is of the opinion, as are by far the greater number of physicians, that syphilis is caused by specific microorganisms, but that this species of bacteria has not yet been demonstrated with certainty.

Transmission of Syphilis to Animals.—Disse and Taguchi claim to have found in the blood of syphilitic subjects, partly by microscopical examination and partly by Koch's culture methods, spore-forming bacilli, by inoculation of which upon animals they have excited in the latter syphilitic diseases. This statement must be regarded with suspicion, as should be the analogous reports of Martineau and Hamonic upon positive transmission experiments, since it has hitherto been the common experience to find that the syphilitic poison cannot be successfully inoculated upon animals. Furthermore, the experiments of Klebs relating to inoculation upon apes, as stated before, yielded doubtful results.

Origin of Syphilis.—Syphilis originates by the poison being directly transferred from one individual to another, particularly during coitus.

The transference of the poison by infected objects is in general rare. The broad condylomata (moist papules, see p. 430) are the most frequent source of the contagion. It has not yet been positively settled whether the contents of the gummata, or in general of the local formations of the tertiary period of syphilis, possess the power of producing infection. The transference of syphilis is only possible when the poison is inoculated in an injured spot, in some interruption of continuity, for instance, of the most superficial layer of the skin, which may often be very insignificant. The syphilis poison reproduces itself apparently only in the human organism, since indisputable inoculations in animals, as stated above, have not hitherto been observed.

The Different Ways in which Syphilis may Originate.—The published statistics upon the frequency of the propagation of syphilis in ways other than by coitus vary greatly. But, in general, an extragenital origin of syphilis is more common in women than in men. This appeared formerly to be of more frequent occurrence than now, probably because the danger of contagion was not so well understood. According to Jullien and Fournier, an extragenital origin of syphilis in men occurs in from five to six per cent. of the cases; in women, on the other hand, in from twenty-five to twenty-six per cent. Mracek (Siegmund's clinic) gives an extragenital infection of one per cent. for men and fourteen per cent. for women.

The different portions of the body which are the seat of the primary extragenital infection of syphilis are, in the order of frequency, as follows: Lips, anus, finger, tongue, breast, abdomen, leg, palate. Finger infection is particularly common in physicians and midwives. Syphilis can also be transferred by the primary lesion on the hands of physicians and midwives to their patients (Neisser). It is not infrequently transferred by infected instruments—for example, in dental operations, in shaving, etc. A careful sanitary police control in the matter of the cleanliness of shaving instruments would certainly be desirable in every respect. It is undoubtedly possible that syphilis may be transmitted by vaccination. Occasionally an entire family may become infected by a syphilitic nurse.

Inheritance of Syphilis.—The question as to whether syphilis can be inherited is of great practical import. As a matter of fact, it has been proved that it can be. Kassowitz has recently investigated this question with great care. The inheritance of syphilis is possible in two different ways: by the poison attaching itself to the spermatozoön or the ovum, or by the healthy fœtus becoming infected from the blood of the mother (intra-uterine infection). It has been proved that syphilis may be inherited in the first of these two ways, and it appears to proceed from the father more frequently than from the mother. The transmission of syphilis by the father alone—that is, by the spermatozoa—has been proved by the fact observed by many authors, such as Hebra, Gerhardt, Weil, etc., that a non-syphilitic mother can give birth to a syphilitic child. The intra-uterine infection, on the contrary, has not hitherto been demonstrated; but it is theoretically conceivable and possible for a woman, who becomes syphilitic during her pregnancy, to infect her

child by means of the blood-channels. But we should not omit to say that Bärensprung and Kassowitz, particularly, have vigorously contested the possibility of this intra-uterine infection, on the ground that it would be impossible for the syphilis poison to pass through the placenta. As a matter of fact, it frequently happens that women with recent syphilis give birth to children who are healthy and remain so.

Still another question is of great practical importance. Can a syphilitic fœtus, originating, for instance, from syphilitic spermatozoa, infect its healthy mother? Such an occurrence is contested, like the above-mentioned intra-uterine infection of the fœtus from the mother, but as a matter of fact it has not as yet been proved.

The recent investigations of Birch-Hirschfeld in regard to the question of fœtal infection are exceedingly interesting (see also p. 416). As he has maintained, the placenta, under normal conditions, is impervious for finely divided foreign bodies and micro-organisms, but the filter may become pervious by pathological processes, or by the lodgement in it of micro-organisms, so that then bacteria in particular, such as tubercle and anthrax bacilli, pass over from the maternal to the fœtal circulation, or rather grow through the tissues.

Kassowitz and others found streptococci in children with hereditary syphilis, especially in the mucous patches. They are to be considered in the main as a result of a secondary infection from a wound of the skin or mucous membrane. In fresh syphilis of the parents the fœtus usually dies before the end of pregnancy. In attenuated late syphilis of the parents the child is more apt to be carried to full term and then born with manifest signs of syphilis, or the syphilis appears soon after birth. Occasionally hereditary syphilis makes its first appearance very late, as Fournier in particular has recently shown. Such cases of syphilis hereditaria tarda are not infrequently confused with scrofula or tuberculosis. When the correct diagnosis is made in such cases, remarkable success can be obtained by the adoption of antisyphilitic treatment. In general the phenomena of congenital syphilis are the same as in the acquired. There are observed the same tertiary manifestations, with serious pathological changes in the skin, the viscera, and the bones (Parrot, Lannelongue). It is important to note that deafness or difficulty in hearing occur rather frequently in hereditary syphilis.

When can a Syphilitic Individual Marry?—The question as to when a syphilitic individual can be given permission to marry is difficult to answer. In general, this should be allowed only when a proper treatment has been carried out continuously, and no recurrences have taken place for from three to four years after the infection.

Symptoms and Course of Syphilis.—If we grant that syphilis is an infectious bacterial disease, its manifestations will be caused partly by the micro-organisms themselves and partly by the toxines which they form. Syphilis usually begins with the appearance at the point of infection of the so-called syphilitic initial sclerosis, or Hunter's induration, or the hard chancre. This specific formation is usually first capable of demonstration two to four weeks after infection, though sometimes

sooner. The primary syphilitic initial sclerosis is usually a hard (indurated), painless (indolent) nodule, which gradually increases in circumference and then most commonly changes into an ulcer. In this way ulcers are formed with a hard, parchment-like base, or the order is reversed, and a vesicle develops first, which ulcerates and then indurates. Often enough the syphilitic initial infection is so small that it is easily overlooked, particularly in women, and the secondary manifestations occurring after a certain length of time are the first indication that syphilitic infection has taken place. Only in rare instances is the syphilitic primary infection complicated by phagedenic changes —that is, by spreading gangrene.

The microscopical examination of the syphilitic initial sclerosis, or of the primary syphilitic scleroma, shows that we have to deal essentially with a collection of round cells, epithelioid cells, and occasionally giant cells (Fig. 295). These cells break down after a certain length of time, giving rise to an ulcer; finally, the disintegrated cells are absorbed, and cicatrisation occurs.

Six to eight weeks after the infection, or later, the constitutional manifestations of syphilis make their appearance, and are due to the fact that the poison has been taken into the circulation from the primary focus of infection and carried through the entire body. The twelfth day is the earliest period at which the outbreak of the constitutional manifestations has hitherto been observed. Occasionally the constitutional symptoms occur very late—for instance, in cases seen by Günz and Rinecker, one hundred and thirty and one hundred and fifty-nine days respectively after infection. Of the symptoms of syphilitic constitutional infection, the first to occur is an enlargement of the lymph glands in different parts of the body; for example, in the inguinal region, at the elbow, in the neck, etc. They can readily be made out by palpation. Then the skin and mucous membranes become diseased. We observe spotted (macular) or nodular (papular), exfoliating (desquamating) or large tuberous eruptions of the skin; also cutaneous ulcers, ulcers on the palate, the lips, tongue, anus, etc. Occasionally the spots upon the skin, particularly in women, have a whitish character (leucoderma syphilitica). In conjunction with a

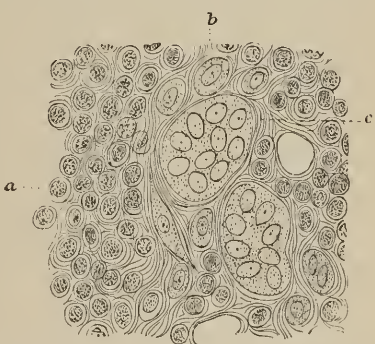


Fig. 295.—Section through a hard chancre: *a*, round celled infiltration; *b*, large mononuclear cells; and *c*, polynuclear giant cells. Hæmatoxylin staining, × 300.

severe syphilitic exanthema there is sometimes observed a circumscribed atrophy, or thinning of the skin, in the form of bluish-coloured areas, in which the cutis forms very small folds. Following the above-mentioned manifestations in the skin and mucous membranes, there occur later syphilitic diseases of the internal organs, particularly the testicle, liver, brain, bones, joints, muscles, and peripheral nerves. Amongst the bones most commonly affected are those of the skull, the tibia, and the sternum. In the skull and nose, as we shall see in the special portion of this text-book, there occur very characteristic losses of substance. The syphilitic diseases of the central nervous system and of the peripheral nerves are of great practical importance. Degeneration of the posterior columns of the cord (tabes) is observed in syphilitic subjects particularly (Erb). The syphilitic poison may be deposited in all the organs and in every tissue and excite chronic inflammatory processes of various kinds, especially in the walls of the vessels, in the form of a syphilitic endarteritis, in which there is a thickening of the wall, particularly of the intima, and a narrowing, or even closure, of the lumen, as has been described by Heubner and others. In other parts there are produced by the syphilitic inflammation either circumscribed growths or diffuse inflammatory infiltrations, with a tendency towards cicatricial formation. Amongst the circumscribed specific formations of syphilis should be mentioned, first of all, the gumma (Virchow), which is also called syphiloma (E. Wagner), and the broad condyloma (condyloma latum). The syphilomata, gummata, or gumma tumours, so called on account of their characteristic elastic property, are observed especially in the testicle, liver, spleen, meninges, periosteum, the marrow of the bones, and occasionally also in the blood-vessels (Virchow, Baumgarten, and Langenbeck). They are either jelly-like formations, with few cells, or nodes made up largely of cells, and more or less like granulation tissue, with the single difference that the new formation of vessels is very limited. By the breaking down of the gummatous nodes extensive ulcerations occasionally result, particularly in the skin. The majority of tumours which make their appearance in the muscles are of syphilitic origin. The muscular syphiloma has a predilection for the sterno-cleido-mastoid, which, according to F. Karewski, is affected in one third of all the cases. In other cases the myositis syphilitica is diffuse. Many of the so-called "rheumatic muscular thickenings" can be referred to syphilitic processes (Braman). The broad condyloma is found particularly about the vulva and the anus. It presents itself in the form of a papillary, moist induration of the skin or mucous membranes, caused by serous transudation and cellular infiltration of the corium or mucous membrane.

The syphilitic diseases of joints (see also Diseases of Joints) which occur in the later stages of syphilis are particularly interesting. Anatomically they sometimes take the form of circumscribed ulcerations or carious processes, fibrillations of the cartilage with the formation of villous excrescences, and sometimes a proliferation of connective tissue or cicatricial tissue in the form of bands, or more diffuse growths. The ulcerative or carious processes are essentially due to the gummatous infiltrations, and the cicatricial tissue is the final result of inflammations of this sort.

Extensive hæmorrhages are observed, particularly in hereditary syphilis, as the result of local diseases of the vessels and the parenchyma (Mracek, syphilis hæmorrhagica neonatorum).

All these diverse manifestations of syphilis which have been so briefly outlined can be divided into three stages.

The first stage includes the incubation period of syphilis—that is, the formation of the local syphilitic sclerosis or the Hunterian induration at the point of infection.

The second stage begins, some six to eight weeks after the infection, with the occurrence of the first constitutional manifestations (swelling of the lymph glands, a macular, papular, or scaly eruption on the skin and mucous membranes), which are accompanied by more or less fever. The other cutaneous affections for the most part appear two to three—less often four to six—months after the infection. According to Siegmund, syphilis can be stamped out at this stage by proper treatment in about forty per cent. of all cases.

The third stage is characterised by the occurrence in the different organs of gummatous forms of inflammation.

Still a fourth stage can be added if so desired, including the syphilitic atrophy and the syphilitic marasmus. In general, the severe form of syphilis passing through all the different stages occurs when the disease does not receive proper care and suitable treatment. Not infrequently cases are observed which run a decidedly malignant course, in which at a relatively early period the internal organs become diseased and severe pustular cutaneous affections make their appearance (syphilis maligna).

The Changes in the Blood in Syphilis, according to Biegański and others, consist in a marked leucocytosis which is due essentially to an increase in the number of the lymphocytes. The number of the red blood-corpuscles is not altered, but the percentage of hæmoglobin is diminished. Under the mercurial treatment of syphilis the amount of hæmoglobin in the blood increases again, and the leucocytosis becomes diminished.

Syphilitic Albuminuria.—The syphilitic albuminuria is occasionally ob-

served at the beginning of the second stage, and is usually completely and permanently cured by antisyphilitic treatment. A second form of syphilitic albuminuria, occurring in the later stages of syphilis, is more unfavourable; it generally marks the beginning of a chronic nephritis (Hortcloup).

Syphilitic Dental Deformities.—Hutchinson, in particular, has directed attention to the syphilitic deformities of the teeth in congenital syphilis.

Syphilitic Pseudo-paralyses.—Syphilitic pseudo-paralyses are observed, according to Parrot and others, for the most part in children two to three months old. Usually the children are suddenly unable to move the affected extremity, most frequently the upper; the extremity is painful, and generally in the region of an epiphysis—the lower epiphysis of the humerus, for example—a diffuse swelling and slight crepitation can be made out. The sensibility and the electrical excitability of the muscles are intact. The fingers can be moved a little. Generally, after a certain length of time, often a few days, the other upper extremity becomes diseased. There may be no other indications of syphilis, but usually traces of past syphilis are present in the parents. Complete recovery ordinarily ensues in from two to three months under antisyphilitic treatment with small doses of mercury.

Syphilis and Carcinoma.—Occasionally syphilis is observed complicated by carcinoma; i. e., syphilitic tissue productions become the seat of a carcinoma, and then present important difficulties in diagnosis which are best solved by careful microscopical examination and antisyphilitic treatment.

The combination of syphilis with tuberculosis is discussed on page 412.

The course of syphilis is, in general, very chronic. It often happens that the syphilis remains latent for a number of years and then breaks out afresh with severe manifestations. Amongst patients with diseases of the brain and spinal cord, we find a great number who have previously had syphilis and had apparently recovered. Watraszewski has stated that injuries to the head or brain, which happen before or after syphilis is acquired, predispose to the occurrence of syphilis of the brain early in the disease. In general one can only be attacked by syphilis once; that is, a patient who has once been infected becomes unsusceptible to the poison—in other words, immune.

Immunity from Syphilis.—The immunity from syphilis exists from the time the syphilitic enlargement of the glands takes place—indeed, as a rule, from the time when the primary initial sclerosis first appears (L. Hudels), and generally lasts till the death of the individual in question. Those who have completely recovered suffer only in rare instances a reinfection, as in other acute infectious diseases, and these reinfections are not unjustly doubted by various authors.

The Soft Chancre.—The so-called soft chancre (*ulcus molle*, see Special Surgery), unlike the primary syphilitic scleroma, the hard chancre, is a local ulcerative process which usually occurs on the glans penis, the foreskin, vulva, or labia, and may lead to inflammation and suppuration of the lymph glands, but never produces the characteristic, syphilitic, constitutional infection.

There has been much discussion between two parties—the unitarians and the dualists—as to the relationship of the soft chancre to syphilis. At present the dualistic view is the most generally accepted—that is, that the soft chancre is an ulcerative process, remaining local, and has nothing to do with syphilis. But weighty authorities including Hebra, Auspitz, Reder and Kassowitz still insist upon the unity of the two processes. This is not the place to enter more minutely into the discussion, and we shall only state that we also share the dualistic teachings advanced particularly by the French physicians, and we lay particular stress upon the fact that the chief means of distinguishing between the hard and soft chancre is not the difference in hardness, since, as a matter of fact, the so-called soft chancre may also show induration, but that the difference in the clinical behaviour is the single and only means of irrefutably proving that the primary syphilitic sclcroma and the ulcerated chancre, which remains local, have nothing to do with one another. It is mainly the long period of incubation of the hard chancre, and the impossibility of auto-infection, which constitute the differences between it and the localised soft chancre. The latter does not have this long incubation, and is capable of being inoculated upon other portions of the bearer's body.

Gonorrhœa.—Gonorrhœa (see Special Surgery) also has nothing to do with true syphilis. Gonorrhœa is either a simple or a mycotic (specific) catarrh of the urethra or of the genital tract, and is produced by a micrococcus, the so-called gonococcus, first discovered by Neisser. Neisser himself states that not every case of gonorrhœa is due to this coccus, but that there is also a gonorrhœa which is not mycotic. Bockhardt excited gonorrhœa with pure cultures of the gonococcus in a paralytic patient during the terminal stage of his cerebral disease.

Treatment of Syphilis—Treatment of the Syphilitic Primary Infection.—If syphilis is a bacterial disease, as it undoubtedly is, it would seem a necessary part of the treatment to extirpate the place of primary infection—that is, the chancre—as soon as possible; and consequently Neisser, Bäumler and others have recently proposed a treatment of this sort in order to prevent, or at least to modify, the constitutional manifestations by removal of the primary germ focus. On the other hand, the propriety of excising the primary syphilitic scleroma has been contested on the ground that this syphilitic primary infection is, after it has made its appearance, the expression of the constitutional disease, and consequently its extirpation is of no avail. I consider this view incorrect; it contradicts our present knowledge of the origin of constitutional disease from a primary focus of infection. Like Neisser, Bäumler, and others, I also try to destroy the primary point of infection in syphilis by excision, by the galvano-cautery, etc., in every suitable case as early and as energetically as possible, before the manifestations of the constitutional syphilitic disease make their appearance. I treat every suspicious ulcer in the same way, even when its syphilitic character has not been rendered certain. Bäumler is right in recom-

mending the removal of the already infected glands in suitable cases in addition to the excision of the primary lesion. Syphilitic ulcerations which appear later are best treated with dusting powders, particularly iodoform, dermatol, oxide of zinc, bismuth, or boric acid, after previously cauterising them with solutions of carbolic acid (1 to 2 alcohol) or chloride of zinc (1 to 8), caustic potash, etc. Washings with bichloride of mercury (0·1 to 100 water), three-per-cent. solutions of carbolic acid, etc., are also to be recommended. The rest of the treatment for local syphilitic disease is conducted, as far as necessary, according to general surgical principles.

Treatment of the Syphilitic Constitutional Infection.—For the treatment of the syphilitic constitutional infection we have two remedies at our disposal—mercury and iodine. Opinions differ as to the value of these substances. According to my own experience, mercury should be used in the early period of constitutional syphilis, and later on iodine and mercury in alternation. The mercurial treatment should begin as soon as the first symptoms of secondary syphilitic disease, in the form of glandular enlargements, make their appearance. The methods of administering mercury are by inunctions of ungt. hydrarg., by subcutaneous injections of the salts of mercury, and by the internal use of mercurials.

Of the different methods of treating syphilis, the best in my experience is the inunction of ungt. hydrarg. In the treatment by inunction, three to five grammes (in adults) of blue ointment are rubbed daily into different areas of skin for about twenty minutes, following a definite order (both arms, the thigh, the forearms, the legs, chest, abdomen, and back). After all portions of the body have been inuncted, the patient then takes a bath and begins the inunctions anew, following the same order. I usually employ three grammes for each of the first ten sittings, four for the next ten, and five grammes for each of the next ten. The mouth must be kept scrupulously clean, to avoid a mercurial stomatitis. The teeth must be cleaned many times a day with a soft toothbrush wrapped in mull, using tooth-powder and water. Every two to three hours the patient must gargle his throat with a one- to two-per-cent. solution of chlorate of potash, boric acid, etc. Smoking should be absolutely forbidden. If, in spite of all this, signs of stomatitis appear, greater care must be bestowed upon the mouth, or eventually the dosage of mercury must be diminished or the mercury must be stopped entirely.

For subcutaneous injection with the hypodermic syringe various double salts are used, such as mercuric chloride, sodium chloride (hydrarg. chlor. corros. 0·1, sodii chlor. 1·0, aq. destil. 10·0, one half

to one syringeful a day), or albuminate compounds of mercuric chloride; 0·1 gramme of the selected compound is injected daily into different portions of the body, particularly the breast and back, or intramuscularly in the gluteal region. The injections which used to be given daily were very inconvenient, and they are at present made less often—every five to eight days, for example—and preference is given to the use of insoluble salts of mercury, particularly calomel, hydrarg. oxidum flavum, etc., which are best injected intramuscularly in the gluteal region. Injections of calomel (0·05 to 0·2 gramme) in glycerine, oil, or salt water, at intervals of four to eight days, are used very frequently. Kopp, Strümpell and others recommend injections of an emulsion of calomel in water with sodium chloride (calomel vap. parat. 5·0, sod. chlor. 1·25, aq. destil. 50·0, one gramme to be injected once a week, altogether four to six times). Calomel oil (1 to 10) is exceedingly good, two syringefuls on the first day, and two more fourteen days afterwards, or every eight days one syringeful (0·1 gramme calomel; Neisser, Doutrelepont, Bergmann). Prochorow recommends one to two per cent. cyanide of mercury (one hypodermic syringeful—altogether about twenty to twenty-five injections). Mention should be made of the following methods of injection: Hydrarg. oxid. nigr. or hydrarg. oxid. rubr. laevig. 1·0, gummi arab. 0·50, aq. destil. 10·0, or 1 to 10 ol. oliv.; a syringeful of this to be injected altogether three to five to seven times at intervals of a week. In a similar manner use is made of the very excellent hydrarg. oxid. flav. 1·0, gummi arab. 0·25, aq. destil. 30, or 1 to 30 ol. amygdal. or olivæ (Strümpell), every week a syringeful in the gluteal region, four to six to eight times. These injections are not so painful as calomel injections, and the formation of abscesses is more easily avoided. E. Lang has practiced injections for many years, with the best results, with oleum cinereum—i. e., a fifty-per-cent. mixture of blue ointment with lanoline and olive oil. Every five to eight days, 0·1 to 0·15 of a cubic centimetre of the ointment is injected in the back or rump. The salicylate and thymolate of mercury have also been much used for injections. Tommasoli praises the curative action of injections of the blood serum of lambs (2 to 8 cubic centimetres daily). This blood-serum therapy of syphilis is analogous to the treatment of other infectious diseases with the blood serum of animals which have been made immune from the infectious disease in question. The mercury injections are somewhat painful, and must always be made by the physician himself, and with antiseptic precautions to prevent abscesses. The injection treatment is in all respects very convenient and cheap for both dispensary and private practice, but I doubt whether it is as valuable as the inunction treatment.

Internally the following preparations are especially used: Bichloride of mercury (0·05 to 0·1 gramme *pro die*) and calomel (0·05 to 0·1 gramme, three times a day in pill or powder). Calomel is also given in large doses (e. g., 0·1 to 0·5 gramme morning and evening), when it is desired to obtain the effects of mercury quickly. Lustgarten and others have recommended hydrarg. tannicum oxydulatum in powder or pill form, according to the following formula: Hydrarg. tannici oxydulat. 4·0 grammes, extr. et pulv. liquirit. q. s. ad pilul. no. 60; three to five pills a day for adults, for children smaller doses of 0·02 to 0·03 gramme. Gamberini, Schadeck and others recommend hydrarg. carbol. oxydat. (hydrarg. carbol. oxyd. 1·2 gramme, extr. et pulv. liquirit. q. s. ut f. m. pilul. no. 60, two to four pills daily). Schadeck has also recommended this remedy for subcutaneous injections (hydrarg. carbol. oxyd. 2·0, mucil. gummi 4·0, aq. destil. 100·0, one syringeful [0·02 of the hg. salt] every two to three days). Recently the salicylate of mercury has been much used internally (1·0 gramme in 60 pills, three to four pills daily), and for subcutaneous injections (hydrarg. salic. 0·20 gramme, mucil. gum. arab. 0·30 gramme, aq. destil. 60·0 cubic centimetres, six to twelve injections to be given within a period of two to three days). After injections of hydrarg. salicylat. a rise of temperature, night sweats, polyuria and other allied effects are observed (Petersen, Lesser, Lang). Leichtenstern and Eich observed recurrences in more than thirty per cent. of the cases treated with salicylate of mercury, some of them very severe, and coming soon after the termination of the treatment.

Excretion of Mercury—Mercurial Cachexia.—According to recent investigations, mercury is excreted mainly in the fæces and in the urine, but in the latter not constantly. The excretion of mercury in the fæces continues for weeks or months after the treatment has ceased. Schuster found the fæces free from mercury one year after the cure. Vajda, Paschkis and Oberländer came to the conclusion that mercury is sometimes retained within the body for years. In former times, especially, the use of mercury was dreaded because there would occasionally arise an incurable mercurial poisoning (mercurial cachexia). It is a generally accepted fact at the present time that this trouble can be avoided with certainty by careful use of the remedy.

Iodine is suited, particularly for the late period, for the gummatous inflammations, though it is also given by many—Zeissel, for instance—in the early stages. He only employs mercury late in the disease and in necessary cases. Iodide of potassium or iodide of sodium is given in a dose of about one to two grammes, seldom more (8 to 10 grammes), daily, best in aqueous solution. In suitable cases very large doses of iodide of potassium (20 to 30 grammes and more *pro*

die) have been administered, accompanied by a milk and meat diet, with bromide of potassium and antipyrine to prevent the iodism and headache. Many recommend the simultaneous use of the iodine and mercurial treatment. Güntz praises bichromate of potassium, particularly for syphilis maligna (one bottle of chromium water every day with 0·03 gramme of bichromate of potassium). In syphilis maligna mercury should be used with the greatest caution. Iron and the quinine preparations are to be recommended, as well as a strengthening diet, proper hygienic measures, and iodide of potassium, together with a suitable local treatment.

The proper nutrition of the patient should be carefully attended to; a moderate amount of alcohol should be permitted, and exercise in the fresh air is desirable, etc. In the inunction treatment, particularly, attention should be paid to keeping the bowels regular.

For recurrences, constitutional treatment, best by inunctions, should always be undertaken again for a time.

It is well known that occasionally, after an apparent cure which may have lasted years, severe local and constitutional manifestations make their appearance. For preventing this, Fournier and Neisser have urgently recommended the use of mercury or iodine for one and a half to two years at proper intervals after the syphilis has been apparently cured. When possible, I usually employ during the first two years after the infection, even in the cured cases, two courses of inunction each half year (12 inunctions of 5 grammes ungt. ciner. each).

In children with hereditary syphilis, for example, it is an excellent plan to use mercurial baths (2 to 5 grammes in a bath lasting half an hour). The internal administration of calomel (0·005 to 0·01 gramme twice daily) or of bichloride of mercury (0·005 gramme *pro die*) easily produces disturbances of digestion.

In the treatment of syphilis, the healthy individuals with whom the patient constantly comes in contact should always be protected from infection by proper precautions.

It is probable that the mercurial treatment of pregnant women can also exert a direct influence upon the syphilis of the fœtus infected at the time of conception, as Zweifel, Gusserow and others have proved that various drugs, like chloroform, salicylic acid or iodine may pass from the maternal into the fœtal circulation.

§ 85. **Leprosy** (*Lepra*).—By lepra (*elephantiasis Græcorum*) or leprosy is understood a chronic infectious disease which is caused by the bacillus lepræ, first discovered by Hansen and Neisser, and is characterised anatomically by more or less circumscribed inflammatory growths,

particularly in the skin and nerves. According to A. Hansen and Bergmann, lepra is contagious, but not in the ordinary sense of the word, as the attendants upon such patients are only very rarely affected by the disease (Beaven). Bergmann found contagion to be the exciting cause in sixty per cent. of the cases (one hundred and eight). Transmission by inheritance can only rarely be proved, the disease in these cases originating for the most part in the family by contact from person to person. Various authors deny the contagiousness of leprosy.

The Lepra Bacilli (Fig. 296), first demonstrated by Armauer Hansen and then by Neisser, are small rods about four to six μ long and almost one μ broad, and are exactly similar to the tubercle bacilli, except that they are somewhat shorter. The lepra bacilli are incapable of spontaneous movement. It is impossible as yet to say whether the bright egg-shaped or round uncoloured spots, which come out when the bacilli are stained, are to be regarded as spores or not. The bacilli are found in the leprous new growths in the skin, nerves, lymph glands, spleen, liver, and testicle, usually in great numbers, partly free in the tissues and partly within the cells in the so-called "lepra cells" (Fig. 296, Neisser, Leloir, etc.). These cells are, some of them, large mononuclear cells, while others are like leucocytes. Wynne found the bacilli also in spindle-shaped granulation cells, and in rare cases in giant cells, sometimes in great numbers (Boinet, Borrel). According to Unna, the bacilli lie preferably in the lymph spaces of the tissues, and the collections of the bacilli designated as "lepra cells" are artificial products, as he thinks has been proved by his drying method. After decolourising the preparation in nitric acid and distilled water, he dehydrated it, not by alcohol but by heating it over a flame, and then clarified it with xylol. Neisser and Wynne, in particular, have contested this view of Unna's.

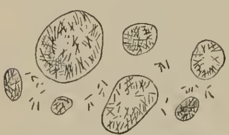


Fig. 296.—Lepra cells with bacilli, × 700. (Flügge.)

The lepra bacilli can be stained in the same manner as the tubercle bacilli, but more easily and rapidly, by using, for instance, solutions like those of Ziehl and Ehrlich. Gram's method is also very useful. But, in contradistinction to the tubercle bacilli, the lepra bacilli, like the majority of all other bacteria, can be stained by the simple aqueous solutions of our aniline dyes, particularly by fuchsin, and methyl violet (Baumgarten). The artificial cultivation of the bacilli and their successful inoculation upon animals has hitherto been accompanied with difficulties, and though there can be no doubt at all as to the specific pathogenic significance of the bacilli, still a perfectly satisfactory proof of their specific action has not as yet been obtained. Bordoni-Uffreduzzi was the first to cultivate the bacilli obtained from the bone marrow of a man dying of leprosy ; he cultivated them at the incubator temperature upon hardened blood serum to which had been added peptone and glycerine, and after several days obtained band-like, whitish-grey colonies with indented borders made up of bacilli of different lengths, generally with a club-shaped enlargement at the ends. Inoculations upon animals

were unsuccessful, because the strictly parasitic bacteria rapidly lose their virulence when cultivated outside the body (Bordoni-Uffreduzzi, Baumgarten). On the other hand, inoculations of leprosy by means of particles of tissue from leprous nodes, made upon a criminal condemned to death, were completely successful (Arning). Melcher and Ortmann claim to have made successful inoculations upon rabbits. Wesener, Leloir, and others, on the contrary, only obtained negative results in animals, and consequently are of the opinion that animals are immune from leprosy. It is certain that man is the chief sufferer from the leprous poison ; but how the disease originates in man and spreads is still uncertain. In the majority of cases the disease appears to spread from person to person by contact—that is, by direct contagion ; inheritance plays a small part. Hutchinson's idea that leprosy is spread by eating fish is contested by a great many. According to Hansen, leprosy is not inheritable. Wahl maintains that leprosy originates preferably in the periphery of the body—that is, in the exposed skin and mucous membrane of the pharynx and larynx, and then very gradually extends to the internal organs by means of the lymph channels. According to Thoma, the leprous new formation begins in the inner layers of the skin, in the perivascular spaces, and in the immediate neighbourhood of the smaller blood-vessels, and then penetrates into the subcutaneous fatty tissue, the lymph vessels and lymph glands. Leprosy attacks almost all the organs of the body, but is localised particularly in the skin and peripheral nerves. Nodules are gradually formed like those in tuberculosis. Large nerves, like the median and ulnar, may swell into strands the size of a finger. In the nerves of a patient with lepra anæsthetica the bacilli are found in the nerve fasciculi, and, besides atrophy and disappearance of the nerve fibres, there is an interstitial sclerosis with sometimes calcareous infiltrations. In the nerve sheaths the leprous disease extends chiefly towards the central nervous system, and in the diseased areas there may be a complete destruction of the nerves, in consequence of which a descending (not leprous) degeneration takes place in the separated portion of the peripheral nerves, involving both the motor and sensory fibres. This explains why every sign of leprous disease is, in certain cases, absent in the peripheral nerves of the area of skin rendered anæsthetic ; in such cases the disease is located in parts of the nerves more centrally situated (Dehio-Gerlach). Of the internal organs, especially the lymph glands, the spleen and liver are diseased. In the blood usually no bacilli can be demonstrated ; but Köbner, Thoma and Doutrelepont have seen them in the blood and the capillaries of the liver.

Occurrence of Leprosy.—Leprosy has been known since the earliest times, and during the middle ages was distributed through almost all the countries of Europe. At present, in Europe, the disease is found only in Sweden, Norway, Finland, in the Russian Baltic provinces and on the coasts of the Mediterranean and Black Seas, and most frequently on the coasts of Norway and in the south of Spain. Leprosy is widely distributed in different parts of Asia (Asia Minor, Persia, China, India), in America (Central America, north and east coasts), in Africa (Cape Colony), and in Australia.

Symptomatology of Leprosy.—Leprosy usually begins very insidiously, the duration of the incubation, according to Bergmann and

others, generally being three to four to five years. A general distinction is made between leprosy of the skin and of the nerves, though, for the most part, they occur in combination. Leprosy of the skin is observed particularly on the face and on the hands and feet, and especially on the extensor aspect of the knee and elbow region. At first there appear hyperæmic spots (lepra rubra), which either disappear, leaving behind a pigmentation, or gradually grow, forming brownish-red nodes the size of a walnut (lepra tuberosa). The nodes, consisting essentially of granulation tissue, may remain stationary for a long time, or they may break down and form ulcers, particularly when subjected to external injurious influences. The leprous nodes develop the most vigorously upon the face, sometimes singly, but generally in groups, forming whole clusters. In consequence of the coalescence of the nodes thick masses result on the eyebrows, the alæ of the nose, the lips and chin, so that the physiognomy of such a patient assumes an expression more or less like that of an animal, and hence the designation lepra s. facies leonina, or leontiasis (Fig. 297).

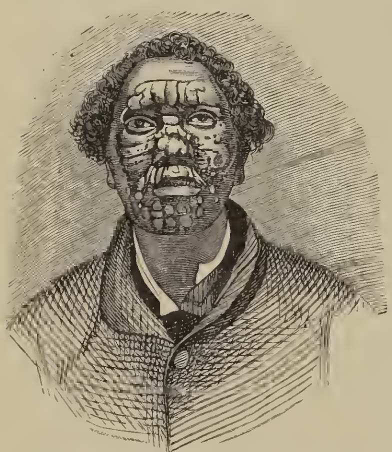


Fig. 297.—Lepra leonina; forty-year-old leper from Cape Colony. (Fritsch and Virchow.)

The leprosy of the nerves (lepra nervorum anæsthetica, lepra mutilans) begins with hyperæsthesia and pain; then anæsthesia usually follows, with trophic disturbances consisting in the formation of white and brown spots and in atrophy of the muscles and bones. Motor paralyses are less common. As a result of the anæsthesia, injuries are not noticed and lead to ulcerative processes, in consequence of which parts of the fingers and toes may be lost (lepra mutilans). The nerves affected by leprous disease become thickened, particularly between the nerve fibres and in the neurilemma, as the result of an interstitial sclerosis, sometimes combined with deposits of lime, etc. Lepra nervorum is essentially a degenerative neuritis ascending from the periphery to the centre (Schultze, Dehio). The minute changes in the nerves occurring in lepra anæsthetica have been briefly described on page 439.

After the skin and nerves, the disease affects particularly the lymph glands, then the mucous membranes, the eyes, nose, mouth, larynx, and also the liver, spleen, and testicles.

Diagnosis.—At the beginning of the disease the diagnosis of lepra can present manifold difficulties. The nodular form may be confused with syphilis, the anæsthetic with syringomyelia. Close questioning of the patient, the histological demonstration of the lepra bacilli, and finally an antisyphilitic course of treatment, may establish the diagnosis in doubtful cases. In syringomyelia, as opposed to lepra anæsthetica, there is usually only a partial disturbance of the sensory sphere—for instance, analgesia and thermoanæsthesia, with persistence of the tactile and muscular sense (P. A. Morrow).

Prognosis.—The disease generally terminates after a varying length of time—one to two to five to twenty years—either with death from exhaustion or from an intercurrent affection, not infrequently from tetanus. Occasionally spontaneous recovery takes place.

Fig. 298.—Actinomyces (ray fungus) with one branching filament separated from the others. (Ponfick.)

Treatment of Leprosy.—Though opinions differ as to the contagiousness of lepra, still all authorities are agreed that it is very necessary for general hygienic reasons to isolate and confine the patients in institutions for the purpose. Wahl, Hellat, Münch and others have vigorously contended for this. As yet we do not know any specific remedy for the disease, and consequently the treatment is essentially a symptomatic one, consisting mainly in proper hygiene, warm baths, and the administration of tonics. In febrile attacks antipyretics are given. For the local treatment, Bidenkap, an excellent authority on leprosy, recommends goa powder or chrysarobin, which he applies to the nodes and spots on adhesive plaster. In suitable cases surgical treatment is to be adopted. For lepra anæsthetica Mitra recommends nerve-stretching. Cramer scrapes away the disease with a sharp spoon, etc. Massage of the nodes and thickened nerves is said to be of use in many instances.

§ 86. **Actinomycosis.**—By actinomycosis is understood a progressive inflammation and suppuration excited by the ray fungus or actinomyces (Fig. 298), which is observed particularly in cattle, swine, and

man, and is transferable by inoculation (Bollinger, Israel, Ponfick, Wolff). Though the actinomyces used to be ranked amongst the mould fungi (hyphomycetes), Bostroem, in 1885, showed by a special method of cultivation that it belonged to the fission fungi (schizomycetes), and was to be regarded as a variety of cladothrix with branches. Bollinger discovered the actinomyces in cattle, Israel in man, while Ponfick was the first to prove the identity of the actinomycosis of cattle with that of man.

Fig. 299.—Pure culture (linear culture) of actinomyces upon agar.

The actinomyces was observed even earlier by Langenbeck (1845) in a vertebral abscess in a man, and by Lebert (1857) in a case of thoracic suppuration.

Actinomyces.—In the actinomycotic tumours or abscess-like foci there are found characteristic, yellow, solid granules the size of a grain of hemp. If these granules are crushed and the preparation stained for half an hour in hot, carbolised fuchsin, or for twenty-four hours in an aqueous solution of gentian violet, and then placed for ten to fifteen minutes in a solution of iodine in iodide of potassium, then in alcohol, etc., and examined under the microscope, these granules will be seen to consist of a characteristic stellate arrangement of branching filaments which radiate from a common centre and possess peculiar club-shaped enlargements (Fig. 298). In every colony of actinomycetes it is possible at a certain stage, according to Bostroem, to distinguish three elements: 1, Club-shaped formations; 2, a centrally placed network of fungous filaments of varying shape and size; 3, fine, coccus-like bodies (spores), which originate from the fungous filaments and grow into long rods and branching twigs. According to Wolff and Israel, the significance of the coccus-like bodies is still obscure. Domee states that the spores, which can be best examined in potato cultures made at a temperature of 22° to 24° C., originate by transverse segmentation of the peripheral filaments, like the arthrospores in the aspergillus, for example. According to Bostroem, who was the first to make pure cultures of the actinomyces, and according to Moosbrugger, the central network of filaments grows rapidly and luxuriantly, while the nodes of the glands are to be looked upon as products of degeneration incapable of further development. This is contested by Partsch. M. Wolff and J. Israel have cultivated the actinomyces, in the absence of oxygen, upon agar and in the interior of raw hens' eggs, and have successfully inoculated these pure cultures upon rabbits by injection into the peritoneal cavity. The actinomyces colonies, when oxygen is cut off, form

upon agar peculiar yellowish-white vegetations; but when oxygen has free access to the colonies there are obtained, according to Bostroem, characteristic ochre-coloured forms with a chalk-like covering (Fig. 299). Pure cultures of the actinomyces grow upon blood serum, agar-agar, glycerine-agar, and gelatine, as well as in bouillon; growth upon potato takes place more slowly. By injection of pure cultures (upon blood serum, agar, and in bouillon) into the peritoneal cavity of rabbits, Afanassjew obtained typical actinomycosis. Bostroem was not able to transmit actinomycosis by inoculation from man to animals, or from animal to animal. From what has been said, it follows that the actinomyces grows in different ways according to the nature of the nutritive medium and the presence or absence of oxygen. It belongs to the polymorphous bacteria, or rather to the cladothrix species, and may occasionally present itself as a simple rod, the above-mentioned bulbs being absent (Ponfick, Ziegler, etc.).

G. Hesse found in one case of actinomycosis a form of fungus which corresponded neither to the cladothrix described by Bostroem nor to the Wolff-Israel micro-organism of actinomycosis. G. Hesse named his fungus the cladothrix liquefaciens, on account of its great power for liquefying blood serum and gelatine. It is obligate aërobic, germinates from spherules or spores, and grows into long filaments with branches. In the stems of the filaments round spores are developed, which subsequently come away, leaving behind the empty stems.

Outside of the animal body the actinomyces grows by preference upon plants, particularly upon grains of corn.

The actinomyces in a section can best be stained by Gram's method, first with methyl violet, then with Bismarck brown. Weigert gives the section a preliminary stain in orchilla, and then places it in a one-per-cent. aqueous solution of gentian violet, by which the central network of filaments is stained blue and the bulbous periphery ruby red.

Occurrence of Actinomycosis in Animals.—Actinomycosis is observed particularly in cattle, less often in swine and horses. By far the most frequent site of actinomycosis is in the jaws of cattle. In this situation, according to Bollinger, Ponfick, and Johne, hemispherical, simple, or composite elevations and outgrowths are formed, particularly near the angle of the lower jaw. They cause the skin to become thin, finally break through it, and sprout out like a fungus. They have a greyish-yellow appearance, and are of lardaceous consistency. Upon pressure pus escapes, containing the characteristic yellow granules already mentioned. The latter usually consist of a great number of glandular formations clinging together like corals. The smallest elementary granules are macroscopically scarcely visible, and reveal a tangle of filaments, as before remarked, which terminate at the periphery in club-shaped enlargements (Fig. 298). Microscopically there is usually observed in the centre of the nodule the actinomyces gland, with its characteristic radiate or rather stellate arrangement, surrounded by epithelioid, lymphoid, and giant cells (Fig. 300). The nodules break down later, and for the most part suppurate, thus giving rise to a correspondingly extensive death of tissue. The growth of the tumour is very slow; the number of the nodular-shaped growths constantly increases, and, after coalescing with one another, they extend slowly into the surrounding parts. The tumours consist partly of

fibrous connective tissue and partly of granulation tissue, and always contain the characteristic small nodules or foci of suppuration with the fungous glands in the form of the above-mentioned granules. The foci of suppuration are sometimes small and sometimes very extensive. In rare cases spontaneous recovery takes place by cicatricial contraction and calcification. The actinomycetes, which usually grow outside the animal body upon plants, are taken into the system mainly in the vegetable food; but they may also enter through the respiratory tract and any interruption of continuity in the skin. The infection is more apt to occur in cattle living in damp or marshy regions, particularly during or soon after a wet year (Bostroem). The common starting-point of the infection is the cavity of the mouth (jaw, tongue, pharynx), and may be the result of any slight injury to the inside of the mouth produced by stiff pieces of vegetable food, or by a carious tooth, etc. According to Johne and Bostroem, in most of the tonsils of healthy swine there are found barley grains which have a fungus on their surface very similar to the actinomyces. In man, also, infection is most apt to originate from portions of plants, less often from ingestion of actinomycotic meat or milk. By growing into the blood-vessels the primary focus may give rise to metastases in the various organs. Metastases do not usually originate through the lymph channels.

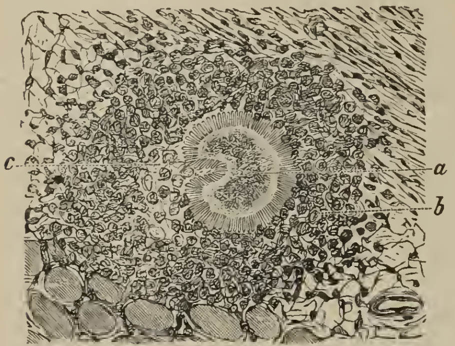


Fig. 300.—Actinomycosis (*a*) of the tongue, with surrounding cellular infiltration (cellular nodule *b*), and tissue in the process of breaking down (*c*), × 200. (Ziegler.)

Actinomyces Musculorum Suis.—The ray fungus occurring exclusively in the muscles of hogs, the so-called actinomyces musculorum suis, discovered by Duncker in 1884, is not identical with the actinomyces bovis s. hominis. Its radiate form is similar, but its relationship to the actinomyces bovis s. hominis is still obscure.

Actinomycosis in Man.—The occurrence of actinomycosis in man was first carefully studied by J. Israel in 1885. He used observations made by himself, and the thirty-eight cases of the disease which were then to be found in literature. The actinomycosis of man can be divided, according to the point of ingress of the infection, into five groups:

1. Cases in which the fungus enters through the oral and pharyngeal cavities, forming a central focus within the inferior maxilla, or becoming localised on the border of the lower jaw, in the submaxillary and submental region, on the neck, or the periosteum of the superior maxilla, or in the region of the cheek.

2. Cases of primary actinomycosis of the respiratory apparatus, with localisation in the bronchial mucous membrane and in the parenchyma of the lungs, spreading to the pleura, the peripleural, and prevertebral tissues, or with extension to the abdominal wall, and finally the formation of metastases.

3. Cases of primary actinomycosis in the intestinal tract, partly as a superficial disease of the intestine and partly with extension of the process to the peritoneum and abdominal wall and the formation of metastases.

4. Cases in which the point of entrance is uncertain (respiratory apparatus, pharynx, intestine).

5. Infection in conjunction with an injury of the skin, cutaneous actinomycosis, particularly after injuries of the skin inflicted by foreign bodies, such as a splinter of wood, for example. Illich, counting in the fifty-four cases which he saw in Albert's clinic, has collected in all four hundred and twenty-one cases of actinomycosis. Of these there were two hundred and eighteen in which the head and neck were affected, sixteen of the tongue, fifty-eight of the lungs, eighty-nine of the abdomen, and eleven of the skin. In twenty-nine cases the point where the infection entered could not be proved with certainty.

Fig. 301.—Actinomycosis of the right side of the neck, with numerous fistulæ leading to foci of pus, surrounded by indurated tissue. The patient is a thirty-year-old peasant. Recovery.

Actinomycosis originates in man chiefly from parts of vegetable matter to which the fungus clings. Portions of vegetable matter, especially barley grains, have been repeatedly demonstrated in the actinomycotic foci (Bostroem, Illich, etc.). Infection by eating actinomycotic meat, or

by drinking milk, is very questionable. The actinomycosis of man differs from that of cattle by the smaller size of the tumours and by the preponderance of thickening and induration of the tissues. The clinical pictures of actinomycosis in man vary very much according to the primary location of the disease. Sometimes the phlegmonous type of inflammation with a suppurative breaking down preponderates; in other cases the formation of granulations or the induration are most prominent (Fig. 301). The disease may begin as a phlegmonous inflammation about the lower jaw, forming epulis-like tumours, especially when there are carious teeth present, as in a case which I operated upon a short time ago. The process may extend from the mouth or from the jaw to the prevertebral tissue of the cervical and dorsal vertebræ (prevertebral phlegmon), with secondary destruction of the vertebræ. Not infrequently cases are observed which run an acute course, presenting the picture of a very acute or even septic suppuration, for example in the neck, simulating *angina Ludovici;* but this is usually due to a mixed infection, as Partsch and others have insisted, since the actinomyces does not by itself excite suppuration. Occasionally actinomycosis runs a course resembling chronic pyæmia, with the formation of multiple abscesses; or the disease begins in a very insidious manner, as primary actinomycosis of the intestine or lung, with secondary extension to the peritonæum, heart, pleura, and eventually the formation of metastases, etc. The latter may become very numerous, as happened in one case of Sonnenburg's, in which the pleura, lungs, the large abdominal organs, and the skin of the thorax, abdomen, back and thighs were involved. The primary location of the affection could not be determined.

In a pure actinomycosis without any mixed infection, such as with pus cocci, the lymph glands are usually not affected, and the metastatic infection takes place not through the lymph vessels but through the general circulation. Bollinger saw one case of primary actinomycosis of the brain in a twenty-six-year-old woman with bad teeth, who had for a long time drunk raw goats' and cows' milk as well as eaten raw meat. The rather rare cases of isolated cutaneous actinomycosis sometimes take the form of cutaneous ulcers, and sometimes of nodular eruptions like tubercular lupus (Leser).

Diagnosis of Actinomycosis.—The above-mentioned characteristic yellow granules which are found in the pus or in the granulation tissue, as well as the microscopic demonstration of the fungus, are of great importance in making the diagnosis.

Prognosis of Actinomycosis.—The prognosis depends mainly upon the situation of the disease, and is always favourable in those cases in

which the diseased parts are accessible to surgical treatment, for example, when they are located in the region of the cheeks, the jaw, the cavity of the mouth, the neck, etc. As Schlange has correctly remarked, actinomycosis has a pronounced tendency to get well spontaneously—a fact which is particularly noticeable when, in actinomycosis of the neck or cheek, the fungi have penetrated beneath the skin and then are finally cast off as foreign bodies. The great majority of all cases of actinomycosis which are accessible to surgical treatment can be permanently cured. The prognosis of actinomycosis of the internal organs is very unfavourable.

Treatment of Actinomycosis.—The treatment of actinomycosis is wholly surgical; it consists in extirpation or in incision followed by energetic scraping out and disinfection of all accessible foci. The actinomycosis which is accessible to surgical, that is, to operative treatment—for example, actinomycosis of the cheeks, tongue, jaw, the oral cavity, the neck, etc.—always has a favourable prognosis, as remarked before, and a permanent cure is generally obtained, provided only the actinomycotic focus is thoroughly removed. I operated on a case of actinomycosis in a young milkmaid involving almost the entire lower jaw. The loosened teeth subsequently became perfectly firm, and the restoration of the lower jaw was very satisfactory. In case of infection of the internal organs, with diffuse foci located in the thoracic or peritoneal cavities, all treatment is usually unavailing, and even the recognition of the disease may present the greatest difficulties.

CHAPTER II.

INJURIES AND SURGICAL DISEASES OF THE SOFT PARTS.

(SKIN, CELLULAR TISSUE, MUCOUS MEMBRANES, BLOOD-VESSELS, LYMPHATIC SYSTEM, NERVES, MUSCLES, TENDONS, TENDON SHEATHS, BURSÆ.)

Wounds of the soft parts (incised wounds, punctured wounds [phlebotomy], contused and lacerated wounds).—Treatment of wounds of the soft parts (hæmostasis, tenorrhaphy, neurorrhaphy [muscle- and nerve-regeneration], suture of a wound, dressing).—Treatment of the conditions following severe loss of blood (transfusion, salt infusion).—Burns; sunstroke; injuries from lightning; congelation; gunshot wounds of soft parts; of bones and joints.—Subcutaneous injuries of soft parts (contusion; subcutaneous rupture of tissue; muscular hernia; dislocation of tendons and nerves).—Inflammations and diseases of the soft parts (skin, cellular tissue, mucous membranes, arteries, veins, lymphatic system, nerves, muscles, tendon sheaths, bursæ).—Gangrene of the soft parts.

§ 87. **Wounds of Soft Parts.**—Of the various kinds of wounds of soft parts, the simple incised wounds are the ones which present most clearly for the beginner the symptomatology of wounds of soft parts, and hence we shall begin with them.

Symptomatology of Wounds, particularly Incised Wounds.—The chief symptoms revealed by every wound are pain in the wound, hæmorrhage, and gaping of the edges of the wound.

Wound Pain.—The degree of pain from a wound varies with the peculiarities of the individual, the portion of the body affected, and the nature of the injury. Every one knows that the susceptibility to pain manifested by different people is very variable. As regards the location of the injury, wounds of the fingers, lips, nose, the external genitals and bones are particularly painful. The division of a sensory or mixed peripheral nerve is accompanied by overpowering pain, while division of the white matter of the brain, in spite of the numerous nerve fibres it contains, causes no pain to speak of. If the division of the tissues is done rapidly with a sharp instrument, the sensation of pain is less than when it is done slowly and with blunt instruments. Consequently it is best, particularly in patients who are not chloroformed, to operate with a sharp knife, and to divide the skin, with its rich supply of nerves, rapidly by a single stroke. In battle, the tissues are divided so quickly that the pain from wounds is but slight.

The subjective feeling of pain accompanying the injury is less important for the physician and has less bearing upon the treatment than the other objective, perceptible symptoms—the hæmorrhage and the gaping of the margins of the wound.

Gaping of the Wound.—The gaping of the wound—that is, the separation of the divided soft parts—is caused by the tension and elasticity of the tissues and by the contractility of the muscular elements. Hence it is natural for the skin, fascia, tendons, muscles, vessels, nerves, etc., after being divided, particularly if in a transverse direction, to be pulled asunder.

Hæmorrhage.—The hæmorrhage (extravasation) is the most important manifestation in the wound. In every division of tissue, lymph, in addition to blood, is poured out of the divided lymph spaces and lymph vessels; but the outflow of lymph is arrested partly by coagulation and partly by even a very slight resistance in the wound, as the amount of pressure in the lymphatic vessels is very small, being no greater than in the surrounding tissues. Besides the blood and the lymph, when injuries involve such structures as glands, joints, etc., there may be an escape of the fluid peculiar to these organs, such as glandular secretion, synovia, etc.

We are mainly interested in the extravasation of blood from the vessels—hæmorrhage. This is either arterial, venous, or capillary—i. e., parenchymatous.

Arterial Hæmorrhage.—Arterial hæmorrhage is characterised by bright-red blood which spurts in a smaller or larger stream from the injured vessel. When there is danger of asphyxia, the colour of the arterial blood is not bright red but dark red, like venous blood; indeed, in bad cases of asphyxia, shortly before death, the blood has a remarkably dark-red or even an actually black colour. Under such conditions, as a result of the threatening cardiac paralysis, the blood pressure in the arterial system is so lowered that the blood does not spurt forth in jets, but flows more continuously or suddenly ceases entirely, as we have described, for example, on pages 26 and 27, in case of threatened death from chloroform. The bleeding from small arteries usually ceases of its own accord from retraction and contraction of the arterial walls and from the pressure of the surrounding tissues. In larger arteries the bleeding does not stop of itself, and the injured person bleeds to death unless the hæmorrhage is arrested by artificial means. The amount of the hæmorrhage depends, of course, when the artery is entirely divided, upon the size of the vessel, and, when partially divided, upon the size of the opening in the wall of the vessel. Longitudinal wounds of an artery are not so dangerous as transverse ones,

as the latter gape more, and consequently render spontaneous arrest of the hæmorrhage difficult. A transverse division of a large artery such as the common carotid, the brachial, or femoral, will be followed by death from loss of blood in a short time, except in the case of punctured wounds, or in contused and lacerated wounds. In contused and lacerated wounds, even in those resulting from tearing away an extremity, the hæmorrhage may be very slight. The contused and lacerated vessels are crushed, and, in the case of arteries, the media and intima are rolled inwards, while the adventitia is likewise twisted or pressed together; hence the bleeding is only slight. But in all contused wounds secondary hæmorrhage very frequently occurs when the contused portion of the vessel or the thrombus sloughs off. Secondary hæmorrhage also readily results from punctured wounds of arteries which have been closed by a temporary contraction of the elastic arterial wall, by a blood-clot or through the wound in the skin.

Hæmorrhage from the Veins.—In hæmorrhage from the veins the dark-red blood flows out more continuously, and when a vein is completely divided it flows most readily from the peripheral end. In large veins, when the valves are insufficient, or when in the neighbourhood of the injury large branches open into the main vein, the blood flows backwards out of the central end. Under these conditions hæmorrhage takes place from both ends of the divided vein. Hæmorrhage from the large veins in the neighbourhood of the trunk is particularly dangerous to life if aid is not at hand; the dark-red blood usually wells forth in great quantities. But patients have occasionally bled to death even from varicose veins of the leg. The reasons for such severe hæmorrhage are that the return flow of venous blood from the dilated veins of the leg is rendered difficult by the dependent position of the veins and by the partial obliteration of the venous channels by previous inflammatory thrombi, and that the patients often have absolutely no idea of how to help themselves. Under such circumstances, instead of elevating the leg and compressing the wound with the finger, they use the strangest kind of methods for arresting hæmorrhage.

Hæmorrhage from Capillaries.—The hæmorrhage from the capillaries and small veins usually ceases spontaneously in consequence of the retraction of their walls, and particularly because of the coagulation of the blood (see page 292). It is well known that the blood which leaves the vascular passage coagulates, and a blood-clot, a so-called thrombus, forms in the wound in the vessel (see pages 290, 291), which not only shuts off the communication of the vessel with the exterior, but also extends for some distance into its lumen. In this way the

hæmorrhage ceases, provided the blood-clot is not washed away by the blood current. The thrombosis takes place the more rapidly and certainly the less the blood pressure is in the vessels, particularly the capillaries and small veins. But the spontaneous closure by a thrombus of a wound in an artery or large vein which is adherent to the surrounding parts is difficult or even impossible.

The Results of a Great Loss of Blood.—After a great loss of blood there follows a falling off of the arterial pressure and a cardiac weakness whereby thrombus formation is facilitated. A severe hæmorrhage is thus, in itself, more or less hæmostatic in its effects. In the same way hæmorrhage is much diminished by transitory heart weakness during a fainting spell, even when due to psychic influences. As a result of severe hæmorrhage the blood itself is changed. It becomes richer in colourless corpuscles, which flow out of the vessels of the smallest calibre where they had accumulated, and the lymph, with the lymph corpuscles, also streams with greater rapidity and in greater quantities into the depleted vascular system. Under these circumstances the coagulability of the blood increases, and this again facilitates the spontaneous arrest of hæmorrhage. If a dog is bled to death by repeated phlebotomies, the blood last taken from the animal will often coagulate almost immediately.

Further Manifestations Following Severe Losses of Blood.—The further symptoms following severe loss of blood consist in pallor and coldness of the skin, particularly that of the face and the extremities, in great weakness, spots before the eyes, ringing in the ears, nausea, vomiting, a feeling of anxiety, vertigo, fainting attacks, etc. The certain precursors of rapidly approaching death from loss of blood are severe dyspnœa, stoppage of the glandular secretions, loss of consciousness, dilatation of the pupils, involuntary evacuation of urine and fæces, convulsions which are excited by sensory irritation, such as a needle-prick, etc. The high grade of dyspnœa and the convulsions preceding death from hæmorrhage are a result of the rapid impoverishment of the brain in oxygen, such as occurs in strangulation (Rosenthal). The same set of symptoms, it is well known, make their appearance in the Kussmaul-Tenner's experiment, when by occlusion of the carotid and vertebral arteries an acute cerebral anæmia is excited, or when the return flow of the venous blood is suddenly interrupted.

Powers of Withstanding Loss of Blood.—The power of withstanding loss of blood appears, to a certain extent, to be subject to individual variations. After severe loss of blood every surgeon has seen in a relatively short time—two to three days—threatening symptoms vanish in cases where he expected certain death ; and again, on the

other hand, some patients go into collapse after the loss of very little blood. Very young children may be endangered by an insignificant hæmorrhage, and weakly children a year old have died after a loss of only two hundred and fifty grammes of blood. In strong adults, who are otherwise healthy, the loss of half the total amount of blood is sure to be fatal. Women appear to stand loss of blood better than men. The formation of new blood seems to take place more easily and rapidly in them on account of the periodic replacement of the blood lost in every menstruation (Landois). Fat people and old and weak individuals are very susceptible to loss of blood. The more rapidly the hæmorrhage takes place the more dangerous it is.

Death from Hæmorrhage observed in Experiments on Animals.—In general, the facts which we have ascertained by bleeding dogs to death experimentally are also applicable to man. As much as a quarter of their total normal quantity of blood has been withdrawn from dogs by phlebotomy without causing the blood pressure in the arteries to sink permanently. During the phlebotomy the arterial pressure, of course, falls off rapidly, and the pulse becomes small. But very soon, even in a few minutes, the pulse again becomes stronger, the blood pressure rises, not because the contents of the vascular system have correspondingly increased, but simply for the reason that the arteries contract in consequence of the irritation of the vasomotor centre in the medulla oblongata produced by the anæmia, and thus accommodate themselves to the diminished amount of blood they contain (Landois). The anæmia caused by the loss of blood acts as a stimulant for the centre of the vasomotor nerves. It overcomes the transitory fall in pressure following the loss of a certain quantity of blood which is within the above-mentioned limit. The rapidity with which the blood flows and the frequency of the cardiac contractions remain the same as before the hæmorrhage. But if more than a quarter of its contents is withdrawn from the vascular system—a third, for example—the arterial pressure does not again rise, but remains lowered, the rapidity of the current decreases, and the contraction of the heart becomes slower in consequence of the incomplete filling of the ventricle. But as the vagus centre receives less stimulation in consequence of the diminished arterial pressure, the frequency of the pulse is usually accelerated (Cohnheim). At the same time, a change takes place in the composition of the blood, the water it contains being increased by absorption of the parenchymatous liquids and by the accelerated flow of the lymph from the ductus thoracicus. As a result of the lowered blood pressure the contents of the capillaries do not transude any longer from within outwards, but the reverse condition prevails: there ensues a diffusion and absorption from without inwards (Cohnheim).

In man, a loss of blood amounting to about one half of the total normal quantity always proves fatal; but even a moderate loss, amounting to a quarter of the total quantity, would give rise to serious dangers for the organism in a short time, unless the blood lost were replaced

by a corresponding regeneration of blood. The hæmorrhages, which are difficult to stop and occur in bleeders, as they are called (see pages 57–59), are especially dangerous.

Regeneration of the Blood after a Hæmorrhage.—If the bleeding does not go on to death the blood is restored by absorption from the tissues or from the food taken in, the first to be absorbed being the serum sanguinis, with the dissolved salts, and then the albumen. A longer time is required to form new red blood-corpuscles. The great thirst following profuse hæmorrhage is characteristic. The patients eagerly drink great quantities of water. The regenerated blood is at first abnormally watery (hydræmic) and poor in cells (oligocythæmia, hypoglobulous). As a result of the greater flow of lymph into the blood the number of the white blood-corpuscles is greatly increased, and then their amount falls off; the red blood-corpuscles again attain their usual number, and the composition of the blood gradually returns to the normal. We do not as yet know certainly how the restoration of the red blood-corpuscles takes place. The most generally accepted view is that colourless corpuscles are being constantly formed in the lymph glands, in the spleen, the bone marrow, and in the liver, and a certain number of these colourless corpuscles change into the red disks (Neumann, Erb). After moderate losses of blood in animals, Buntzen saw the volume of the blood restored in a few hours, and when the loss was severe, within twenty-four to forty-eight hours. The red blood-corpuscles, after hæmorrhages amounting to from 1·1 to 4·4 per cent. of the body weight, were again complete after the lapse of seven to thirty-four days. The beginning of the regeneration was proved to take place after forty-eight hours.

Entrance of Air into the Veins.—Amongst the dangers which may follow an injury to a vein, particular mention should be made of the entrance of air into the vein, a matter which we discussed on page 60.

Of the other symptoms caused by wounds, those are of especial importance which indicate division of the muscles, tendons, and nerves, or the opening of a joint or a cavity of the body. I shall refer to the latter complications under Injuries of Joints, and in the Text-Book on Special Surgery (injuries of the cranial cavity, thorax, and abdomen, and of the separate joints).

Division of Muscles and Tendons.—The symptoms which indicate a division of muscles and tendons are very simple; they consist in disturbance of the function of the affected muscle, and, in addition, the divided muscles and tendons can usually be seen at once when the incised wound is carefully inspected.

Division of the Nerves.—The symptoms following division of the peripheral nerves (we omit incomplete divisions, contusions, and punctures of nerves) consist likewise in a corresponding functional disturbance of the affected peripheral nerve—in other words, in sensory and motor disturbances.

Degeneration of Nerve Fibres cut off from their Centres.—Nerve fibres cut off from communication with the central nervous system after a time lose their excitability; they undergo a fatty, granular degeneration, which involves the entire separated portion of the nerve down to its finest peripheral branches (Müller, Waller). The sensory fibres, according to Waller, degenerate not in the peripheral but in the central portion when the posterior root is cut above the spinal ganglion. The spinal ganglion consequently plays the same part in the preservation of the sensory fibres that the spinal cord does for the motor. The paralytic degeneration probably occurs simultaneously in the whole length of the peripheral portion, not spreading from the point of section towards the periphery, nor beginning, as Schiff describes it, in the peripheral network. The contents of the nerve finally disappear completely, and probably the empty neurilemma also. The connective tissue of the nerves is the seat of an inflammatory, nuclear proliferation. There is still a division of opinion as to whether or not the degeneration likewise involves the peripheral end organs, such as the tactile corpuscles, the rods of the retina, the terminations of the olfactory nerves, etc. Recently F. Krause has carefully studied the ascending and descending degeneration of divided nerves, and he states that all the sensory fibres in the peripheral segment of the nerve which are connected with a trophic centre in the periphery, such as Meissner's tactile corpuscles, remain intact, but the central segment of the nerve undergoes degeneration. On the other hand, all the motor nerve fibres and the sensory fibres of the bones, periosteum, joints, muscles, tendons, and the sensory fibres terminating free in the skin persist in the central nerve segment and degenerate in the peripheral portion of the nerve. At the same time that these degenerative processes are taking place in the nerves, the muscles atrophy and in part undergo fatty degeneration.

The disturbances of sensation after division of nerves are not so pronounced as the motor-paralytic manifestations. If, for example, a mixed nerve in the extremities—such as the median or ulnar—is divided, the manifestations of motor paralysis are always exhibited in a typical manner, while the sensory paralysis may be very slight or almost completely absent, because the collateral anastomoses of the neighbouring uninjured nerves take up vicariously the conduction of the sensory impulses. There is an intimate anastomosis between the finer nerve branches in the skin, particularly upon the fingers, and in the face. The individual perceptive senses appear to behave differently after injuries. It sometimes happens that all the senses—that is, the tactile, temperature, and pain sense—are lost after division of a nerve, or they

are more or less retained; while in still other cases only the tactile sense persists while the pain and temperature senses are suspended. Immediately after the injury the disturbances of sensibility are most pronounced, and after four to six days the manifestations of sensory paralysis improve without its necessarily following that a regeneration of the nerve has occurred at the injured point. Indeed, the disturbance of sensibility may disappear more or less completely, though, in fact, no union has taken place between the divided ends of the nerve. The collateral paths gradually take on more and more activity, or new-formed nerve-fibres grow from the uninjured, collateral nerves into the anæsthetic, cutaneous district.

As regards the motor disturbances, the muscles supplied by any particular motor or mixed nerve are always paralysed after division of this nerve. The position of the hand, for instance, after division of the musculo-spiral, median, or ulnar nerve, is always a typical one (see Special Surgery). Variations from the general rule of course may occur when there are anomalies in innervation. There is observed, however, after nerve division, especially in the subsequent course of the case, more or less substitution in the sense that other muscles, supplied by an uninjured nerve, perform singly or in groups the duties of the paralysed muscles. According to Létiévant, these substitutions may act so perfectly, when occurring between the ulnar and median nerves, for example, that it is possible on superficial examination to overlook an actually existing paralysis of the parts supplied by the divided nerve. Küster and Falkenheim have described analogous cases. If, after division of a mixed or motor nerve, paralysis is partially or entirely absent, the cause is to be ascribed, according to observations made upon such cases by Kraussold, Spillman, and others, to anomalies of innervation or to the persistence of undivided collateral nerve filaments which connect the central and peripheral stump of the divided nerve. The further towards the centre a motor or, rather, mixed nerve is divided, so much the more extensive are, of course, the symptoms of motor paralysis.

Of the other symptoms which follow division of peripheral nerves I should briefly mention the following: Very frequently, indeed almost always, the patients after division of a nerve complain of a marked sensation of cold in the paralysed district. Hutchinson states that the difference in temperature amounts to from 2·2° to 5° C. (4° to 9° F.). Kraussold and Rohden found that the temperature in the paralysed parts after division of the ulnar nerve was lowered as much as 6° to 9·8° C. (10·8° to 17° F.). In rare cases the temperature in the paralysed parts has been observed to be elevated 2° to 5° C. (3·6° to

9° F.). (Haym). Other manifestations are a burning, prickling pain, formication, an increase in the secretion of sweat or a remarkable dryness of the involved area of skin, and, finally, cutaneous affections such as herpes zoster, eczema, pemphigus, ecthyma pustules, disturbances in the nutrition of the skin, such as the formation of eschars, ulceration, or gangrene, especially on the finger-tips. The skin is œdematous, bluish red, or abnormally pale. In the periosteum and bones inflammatory and trophic disturbances are also observed. In the joints there are serous effusions taking the form of chronic hydrarthrosis or subacute articular rheumatism, adhesive joint inflammations, now and then terminating in a stiff joint—anchylosis. The neuroparalytic (neuropathic) joint disturbances, resembling a subacute articular rheumatism, lead to a painful swelling of the joint, and finally to distention and subluxation of the articular surfaces, to marked atrophy of the bone, and to destruction of the whole joint. All of the last-mentioned changes in the bones and joints occur only as the final results following an unhealed division of a nerve. After the paralysis has lasted some time a progressive atrophy of the portion of the body in question takes place not only in the muscles and the soft parts but also in the bones. The electrical excitability of the divided nerves and muscles decreases by degrees, and finally is lost entirely.

I. **Punctured Wounds.**—Punctured, contused, and lacerated wounds present many peculiarities, and it is therefore necessary to study them somewhat more in detail.

Punctured wounds are produced by sharp or blunt-pointed instruments, such as swords, daggers, knives, needles, splinters of glass or wood, etc. Arrow wounds of the Indians, for example, are described in § 82. Punctured wounds belong, in the majority of cases, to simple wounds, and heal comparatively quickly if the injury does not involve deeply lying parts, such as vessels, nerves, joints, or the large cavities of the body with their contents, including the cranial cavity, the pleural or peritoneal cavities. Sharp-pointed instruments in general produce punctured wounds with smooth borders, while blunt-pointed objects are more apt to contuse the borders of the wound. Punctured wounds, as a general thing, correspond in shape to the instrument by which the wound was produced—a fact which is of especial importance in medical jurisprudence.

In a great number of punctured wounds the depth of the wound is disproportionately great in comparison to its length and width, and the nature of the injury is not so apparent as in incised wounds. If large arteries or veins have been injured, the hæmorrhage which appears externally may be relatively slight. If a large artery is punctured, at

the moment of the injury a great bright-red stream of blood spurts out; but after removal of the instrument only a little blood trickles from the wound, because the puncture in the artery has been closed by the elasticity of the arterial wall. Should the hæmorrhage continue from the artery, it does not appear externally, but takes place into the tissues surrounding the vessel, because the soft parts divided by the puncture fall together again, and do not permit the blood to escape to the surface of the body. Under such conditions a large blood tumour forms, a so-called aneurysma traumaticum or spurium, in contradistinction to the aneurysma verum, which is a more gradually developing, sacculated, or spindle-shaped dilatation of an artery. In the aneurysma traumaticum there is heard, upon auscultation with the stethoscope over the blood tumour and so over the point of injury, a systolic *bruit* or murmur isochronous with the pulse, caused by the outflow of the blood through the opening in the artery into the surrounding tissues. This systolic murmur, following a puncture in an artery, ceases immediately when the artery involved is compressed above the point of injury or when the hole in the vessel becomes closed by a thrombus. No sound is heard, however, when the artery is cut completely across. These murmurs are of great diagnostic importance.

Punctured Wounds of Veins and Arteries (*Aneurysma Varicosum, or Arterio-Venosum*).—If an artery and a vein are injured simultaneously by a puncture (as may occur, for example, in phlebotomy when the point of the knife is stuck too deeply into the median basilic vein and penetrates the brachial artery lying under the vein), there may result a permanent communication between the artery and the vein; a sack is formed (Figs. 302, 303), into which flows the blood of the artery as well as that of the vein. This condition is called varix aneurysmaticus or aneurysmal varix, or, better still, aneurysma arterio-venosum.

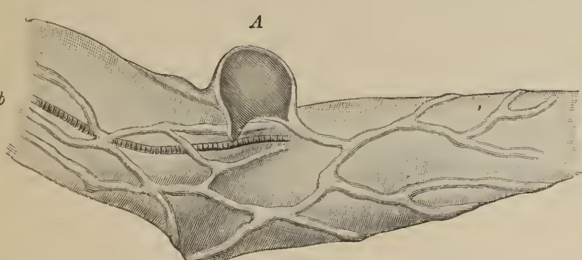


Fig. 302.—Aneurysma arterio-venosum (*A*) at the bend of the elbow resulting from venesection; *b*, arteria brachialis (Bell). The sack *A* of the aneurysm is laid open (Froriep).

Fig. 303. — Aneurysma arterio-venosum (Busch).

Technique of Phlebotomy, or Venesection.—This is perhaps the best place for briefly considering blood-letting. Venesection, or phlebotomy, formerly much used for all sorts of diseases, is at present almost never done in surgical practice. Phlebotomy is performed almost exclusively on the veins of the elbow, particularly the median basilic, which is generally the best developed (Fig. 304). It is to be noted that the vena mediobasilica crosses the brachial artery, and at this point is only separated from it by the very thin aponeurosis of the biceps muscle; consequently before the operation it is best to feel for the pulsation of the artery, and to open the vein either above or below the point where they cross. Phlebotomy is performed in the following manner: In the first place, the middle of the (upper) arm is encircled by a bandage, or piece of folded cloth, to produce venous stasis and a marked distention of the vein. The tourniquet should not be applied so tightly as to close the artery; the radial pulse must therefore persist. The arm should hang down, to permit a more complete filling of the vein. The vein is best opened with a pointed scalpel after the field of operation has been carefully scrubbed with soap, shaved, and disinfected. If the outflow of blood is not free it can be made to become so by muscular contractions—for instance, by opening and closing the hand. When a sufficient amount of blood has escaped, the wound is closed by the finger, the tourniquet removed, and the small wound covered with an antiseptic dressing, which exerts a slight pressure. This small operation must, of course, be carried out with a careful observance of antiseptic precautions. In the preantiseptic days suppurative venous thrombosis and death from pyæmia were of relatively frequent occurrence.

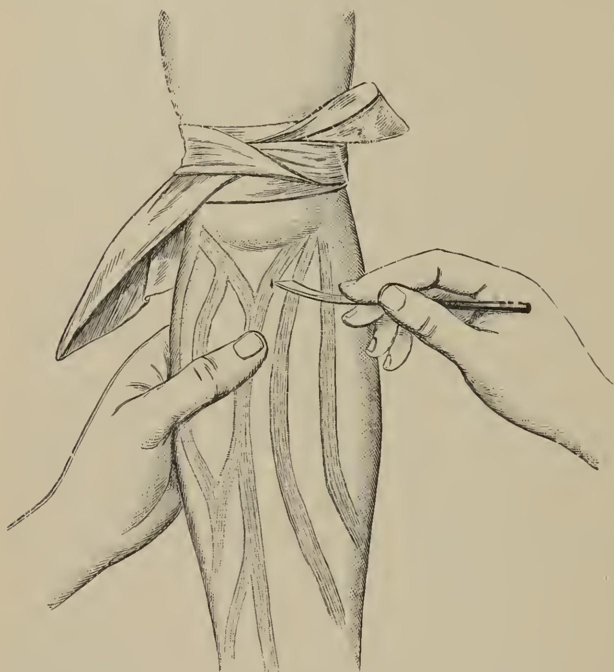


Fig. 304.—Venesection (right arm at the bend of the elbow). (Esmarch.)

Spontaneous healing of a Punctured Wound in a Vessel.—A puncture in an artery can heal spontaneously if there is not too much gaping of

the wound. The small opening is closed by the contraction of the elastic walls of the vessel or by a blood-clot. In the case of larger arteries the formation of a blood-clot closing the hole is rendered difficult in consequence of the high intra-arterial pressure. In smaller arteries, where the pressure is not too great, the coagulum is more likely to remain in position, and the clot extending into the lumen of the vessel may receive fresh layers from the blood flowing by it, and thus there can result a complete closure of this portion of the vessel —in other words, a completely occluding arterial thrombus. But in all cases where spontaneous healing of a puncture in a vessel is accomplished by a clot, there is the danger that the latter may be swept away at any time should there be any considerable intra-arterial pressure, and thus a renewal of the bleeding will take place—a so-called secondary hæmorrhage. Punctured wounds of veins heal spontaneously very readily by becoming closed with a thrombus. The blood coagulates easily here on account of the slight intravenous pressure, and the walls of the veins collapse if not prevented from doing so by natural adhesions to the surrounding parts, such as fascia or bones. After veins have been wounded there result extensive venous thrombi, which, especially in the preantiseptic days of surgery, used to be greatly dreaded, as they often underwent suppuration with subsequent general septic poisoning (pyæmia).

Punctured Injuries of the Nerves.—Punctured injuries of the nerves may either completely or, more often, partially divide them, and are of special practical import. The extent of the paralysis caused by the injury to the nerve depends upon the number of the nerve fibres which have been divided. If the nerve is not cut entirely through, spontaneous healing usually follows without surgical interference, in case the nerve was at the same time not too much contused. In one instance I saw an irremediable paralysis of the ulnar nerve follow a punctured wound of the nerve made by a steel pen filled with ink. The nerve was months afterwards coloured black throughout a large part of its extent. Small foreign bodies, such as needle points, bits of glass, etc., may become encapsulated, and they often give rise in sensory or in mixed nerves to very painful cicatrices and cicatricial tumours (neuromata) or to epileptiform attacks. Before the attack begins the patient usually feels a pain in the cicatrix.

Punctured Wounds of Joints and of the Large Cavities of the Body.—During the first few hours or days after the injury there may often be doubt as to whether a joint or a large cavity of the body, with one of its vitally important organs, has been injured. It is true that punctured wounds entering joints or cavities of the body not infrequently

heal up without treatment; but in other cases it becomes evident, after the lapse of a few days, that the punctured wound has given rise to suppuration in the joint, or that some important internal organ has perhaps received such injuries as to cause death.

Traumatic Emphysema.—In conclusion, mention should be made of the occurrence of air in the neighbourhood of punctured wounds—traumatic emphysema, as it is called. If, after punctured wounds, air collects to a greater or less extent in and under the skin, there will be felt a slight crepitation in the affected areas. The air can be easily removed by pressing and kneading with the fingers. Traumatic emphysema, or the collection of air, especially in the subcutaneous cellular tissue, may be due to an injury to an organ which contains air, such as the lung or trachea. After injuries of the lung the air may spread beneath the skin over the entire body wherever it meets with the least resistance. Air can also be sucked into the wound from without by aspiration. It is well known that there also occasionally arises a so-called "spontaneous" or primary emphysema after subcutaneous extravasations of blood, especially in fractures (Velpeau). According to H. Fischer, this is due to gases from the blood which are set free by the action of an acid, such as the lactic acid which is present in the contused tissues. This so-called spontaneous emphysema can be produced experimentally in animals by exciting in them an extensive extravasation of blood, and then injecting lactic acid into the latter. In one case which Fischer observed the gas consisted almost entirely of carbonic acid. A careful distinction must be made between the various kinds of emphysema hitherto described and the emphysema of decomposition—that is, the collection of the gases of decomposition in the rapidly spreading putrefactive processes which may take place in severe open wounds as a concomitant symptom of very advanced sepsis, and in the so-called malignant œdema, etc. (pages 333–336).

Further Course of Punctured Wounds.—The further course of punctured wounds can be inferred from what has already been said; it depends essentially upon whether important, deeply situated organs such as arteries, nerves, joints, the thoracic, peritoneal or cranial cavities, with their organs, are injured or not, and whether excitants of inflammation in the form of bacteria are introduced into the wound by the instrument inflicting the injury, and, finally, whether a foreign body, such as the point of an instrument, is left sticking in the depths of the wound. If all the complications which have been mentioned are absent, then punctured wounds heal very rapidly like simple wounds. If substances which excite inflammation or bacteria have been carried into the wound by the instrument, if a foreign body has been left in

the wound and the wound has not received antiseptic treatment, under these conditions suppuration, abscesses, or a deep and spreading cellulitis may follow, and possibly death from pyæmia and sepsis. After a simple needle-prick of the finger septic cellulitis has been repeatedly observed which ran a fatal course, and with such rapidity that, although a disarticulation of the humerus was performed on the fifth or sixth day, it was impossible to save the life of the patient. Not infrequently punctured injuries heal superficially without suppuration, and yet in their depths inflammation and suppuration take place, especially if a non-aseptic body be present.

Behaviour of Foreign Bodies in a Wound.—Amongst the foreign bodies which may be left behind in a punctured wound are broken-off needle points or entire needles, knife points, sword points, splinters of glass or wood, etc. Knife and sword points are particularly apt to break off after penetrating bones. Not infrequently the foreign bodies remaining in the wound heal in without reaction when they were more or less aseptic, e. g., clean. Needles have been found embedded in the brain and heart (see Special Surgery). E. Simon, while conducting an autopsy upon an adult, found a pin healed up in the brain which had probably been introduced through the open fontanelle during the first year of his life. Huppert, while making the post-mortem examination upon an idiot, found a needle in the heart which extended free into the left ventricle five to six lines. The needle was enclosed by a membrane covered with endothelium, and had caused no particular symptoms during life. It had been in the heart about five years. Foreign bodies frequently leave their original location; they wander—i. e., they are pushed on by muscular contraction and by the elasticity of the tissues. They may get into internal organs and cause serious trouble, or after weeks, months, or years they may reach the skin at some point, not infrequently causing an abscess, from which they are then extracted. Billroth removed a knitting-needle almost a foot long from the inguinal region of a thirty-year-old idiot, whither it had probably come from the vagina or rectum. Needles which have been swallowed also pass, without causing trouble, through the walls of the stomach and intestine and may get into the urinary bladder, where they give rise to a vesical calculus by deposition of urates upon the needle. In another case, a pin which had been swallowed lodged in the œsophagus and killed the patient by puncturing the aorta. There are a great number of recorded cases illustrating the healing in and wandering about of foreign bodies, and I could add to the list a considerable number of surprising ones.

The healing in of foreign bodies is also discussed in § 61.

II. **Contused Wounds.**—The contused wounds belong to the complicated wounds; the tissues are crushed by the force applied by a blunt object. Not infrequently they are a part of very extensive injuries in which the soft parts and bones have been reduced to a pulp. All the various kinds of wounds produced by blunt instruments belong

to the class of contused wounds; such, for instance, are the wounds produced by "run-over" accidents, by the kick of a horse, etc., also the numerous machinery and railroad injuries so very common in modern industries and transportation. Gunshot wounds are, in the main, contused and lacerated wounds, and will be discussed more fully under Gunshot Fractures (§ 124). Wounds caused by bites likewise belong to contused wounds. Bites of rabid animals and poisonous snakes are described in §§ 80 and 81.

Appearance of Contused Wounds.—The appearance of contused wounds differs very essentially from that of incised wounds. The borders of the wound are not smooth and of normal appearance, but, as a result of the bruising, are infiltrated with blood, bluish-black in colour, swollen, and often irregular in shape. The bloody infiltration of the tissues varies with the amount of force to which they have been subjected; not infrequently the extravasated blood spreads to a great distance in the parts around the wound. Occasionally the borders of the wound, or the more deeply lying parts, are so crushed that they subsequently perish. When scratched with a knife no blood flows out, and the patient has lost all sensation in the affected part. The appearance of skin which has been badly crushed varies according to the amount of blood it contains: it may be red shading off into bluish or dark blue, violet, or white, and corpse-like and cold to the touch. Occasionally completely crushed skin looks apparently normal and yet it is dead. Not infrequently the gangrene of the skin does not become evident till several days after the injury. In severe cases of contused wounds the borders of the wound and the injured tissues in general are torn into shreds, the skin is more or less extensively stripped from the underlying parts, the fascia, tendons, nerves, and vessels are mangled; in short, the soft parts are crushed to a pulp and the bones broken into numerous fragments, etc. But in such bad cases of contused wounds the integrity of the tissues is disturbed not only at the point of the injury, but also at some distance from it, in consequence of disturbances in nutrition due to the infiltration of blood. These changes in the neighbourhood of the wound are not perceptible to the eye of a layman, but are recognised by the surgeon, and on account of this bloody infiltration, if there is any necessity for an amputation, he performs it at a point not too near the injury.

Hæmorrhage in Contused Wounds.—When large arteries and veins are injured, such as the femoral, brachial, or axillary, the hæmorrhage, as a general thing, is slight, or may even be entirely absent, for the reason that the injured vessels are crushed at the same time with the other parts, or subjected to torsion, in the same way as described

in § 28, for checking hæmorrhage. At the same time, after such severe contusions there is a high grade of nervous depression, of wound-stupor or shock (§ 63). As a result of this shock the cardiac activity is reflexly diminished and the arteries are contracted, and hence the tendency to hæmorrhage from the injured and contracted arteries is decreased. During the next few days, when the shock passes off and the action of the heart becomes stronger, secondary hæmorrhages may readily occur from the crushed, torn, or thrombosed arteries, and may cause the death of the patient unless prompt aid is at hand. It is on account of these dreaded secondary hæmorrhages after contusions that patients with such injuries should be carefully watched. The hæmorrhages may occur on the first to second day with the abatement of the shock, or they come on later, on the fifth to tenth day, and sometimes later still. The later secondary hæmorrhage may be caused by the sloughing away of the contused portion of the wall of the vessel which has become necrotic, or by suppuration of a thrombus, or by erosion of the artery, as a result of suppuration in its immediate vicinity. But the primary hæmorrhage in contused wounds is not always slight; it often enough happens that there is a considerable amount from both arteries and veins. This is particularly apt to be the case when the arteries are incompletely torn, so that the injured vessel cannot retract or contract. Under these conditions hæmorrhages into the surrounding tissues will also be observed, forming so-called traumatic aneurysms similar to those following punctured wounds of arteries.

III. **Lacerated Wounds.**—Lacerated wounds present essentially the same peculiarities as contused wounds. The larger lacerated wounds have, in general, a mangled appearance. Tearing away of entire extremities—the upper or lower, by machinery, for instance—belong to the severest class of injuries which a surgeon ever sees. In such cases the injured person shows all the symptoms of severe shock, in consequence of which death not infrequently follows. Even when entire extremities are torn away there may be no hæmorrhage of any importance, for the reasons stated above. In the hospital at Zurich an arm, including the scapula and clavicle, has been preserved, which was torn away without causing death by hæmorrhage, as the axillary artery was twisted on itself as in torsion.

Further Course of Contused and Lacerated Wounds.—The further course of contused and lacerated wounds depends upon the severity of the injury, upon the introduction of micro-organisms at the time of the injury or subsequently, and whether the wound receives antiseptic treatment at as early a period as possible. Even very badly contused and lacerated wounds may heal without any marked secretion or sup-

puration if they remain covered by an aseptic blood-clot beneath an antiseptic dressing. The time which contused and lacerated wounds require for healing is longer than that necessary in other wounds. In the case of contusions of any gravity, the wound resulting from the injury usually "purifies itself" from the superficial, mortified, or half-dead tissues, by giving off a discharge or secretion which is at first bloody, then serous, and finally purulent. When the wound is treated aseptically the discharge has no odour, but if putrefactive changes take place it is discoloured, dirty, and often has a characteristic smell. The mortified (gangrenous) and half-dead tissues are cast off by suppuration —that is, at the boundary line between the healthy and dead parts, at the so-called line of demarcation, there ensues a vigorous proliferation of the tissue cells and a collection of wandering cells. Subsequently a cellular and vascular granulation tissue forms, from the surface of which pus is given off in large quantities. By this demarcating suppuration the dead parts are separated from the living. The casting off of the dead tissue goes on with different degrees of rapidity, depending particularly upon the vascularity of the injured tissue. Hence it follows that in the case of dead portions of tendons, fascia and bone, the process takes a particularly long time. Still there are great individual differences in this respect.

Contused and lacerated wounds offer, in general, a favourable medium for bacteria, especially the former. The micro-organisms usually enter the wound at the moment of the injury—for example, when upon a dirty street a wagon-wheel passes over an extremity; or the instrument which inflicts the injury, the dirty clothes, or the skin of the patient, are the means by which the bacteria are carried into the wound. As a result of the presence and development of the bacteria in the wound, the various infectious-wound diseases can originate. These have been described in § 66 *et seq.* After extensive contused wounds, those spreading, septic forms of cellulitis, which we have studied in § 70, are particularly apt to occur. If a contused wound has cast off its mortified layer, and has passed into the stage of granulation, the healing is ordinarily assured if no transgression is made of the rules of antisepsis.

The more minute anatomical changes which take place in the healing of a wound, in the formation of the scar, and the cicatricial contractures, etc., have been described in § 61.

As regards the course of injuries of particular regions of the body, I must refer the reader to my Text-Book on Special Surgery.

§ 88. **The Treatment of Wounds of Soft Parts.**—The treatment of every fresh wound of the soft parts is conducted upon antiseptic

principles, in the manner described in § 6, § 20, and §§ 44–49. The treatment begins with a careful examination of the wound, to determine whether large vessels, tendons, or nerves have been injured, or whether a joint or cavity of the body has been opened. Our first care should be the arrest of the hæmorrhage, as we have described in §§ 27–30. The following brief description of hæmostasis will suffice: On the extremities it can be best carried out with the assistance of Esmarch's artificial ischæmia. The wound, particularly if a punctured wound, must always be enlarged sufficiently to lay bare the point where the vessel has been injured, and to permit of its inspection. Every large artery in the wound which has been punctured or cut must receive a double ligature—that is, the vessel must be tied on the central and peripheral side of the injured point, as only in this way can secondary hæmorrhage be prevented from the peripheral end of the vessel, or from the puncture in the artery (Rose). If only the central end of the artery is ligated, a secondary hæmorrhage could occur from the unligated peripheral end of the vessel, or the puncture in its wall, very soon after the establishment of the collateral circulation. But the central and peripheral ligation of the artery in punctured wounds, for example, is not sufficient. All the branches given off from the vessel in the neighbourhood of the injury must also be secured at the same time, if one wishes to be perfectly sure of preventing hæmorrhage from the puncture in the artery (Rose). After ligating the main vessel and the branches, the injured portion of the vessel can then be extirpated, though it is not necessary. Injuries of large veins are treated in essentially the same manner as those of arteries. As regards the special technique for ligating arteries and veins, I must refer the reader to § 30.

Temporary Hæmostasis.—Often enough the physician, especially in the country, is not so situated as to be able to immediately and permanently arrest the hæmorrhage, but must be content with provisional hæmostasis carried out by some sort of dressing, in order to transport the patient to a hospital. The simplest means of arresting hæmorrhage temporarily consist, as already mentioned in § 29, in applying pressure upon the bleeding point by the finger, a dressing, or an elastic bandage, and in applying pressure upon the afferent artery by the finger, by tourniquets, an elastic bandage, Esmarch's elastic tourniquet (§ 19), and finally by forced flexion—for example, of the elbow joint or the knee if the hæmorrhage takes place in a region supplied by the branches of the brachial or popliteal arteries.

Further Treatment of Wounds of Soft Parts.—When the bleeding has received the most careful attention, it is advisable to examine the

wound thoroughly with antiseptic precautions to determine whether and to what extent deeply placed parts, such as tendons, muscles, nerves, or bones, have been injured, and whether the wound is rendered unclean by the presence of a foreign body. The examination should be performed as gently as possible, and an especial warning should be given against the too rough use of the probe. By means of the latter it is easily possible to penetrate a thin, undivided layer of tissue over a joint, over the peritonæum, the pleura, etc., and thus change a relatively simple wound into a complicated one. We shall go into the treatment of penetrating wounds of joints or of the cavities of the body in another chapter (§ 123, Wounds of Joints). If it is found that muscles, tendons, or nerves have been divided, they must be reunited by sutures.

Tenorrhaphy—Tendon Suture.—The best method of performing tenorrhaphy is Wölfler's. He passes the suture through the tendon stumps transversely, about one centimetre from their free ends, either once or repeatedly, and then ties the ends of the sutures together. Witzel recommends the application of a "retention ligature" passed transversely through each stump of the tendon about one centimetre from its cut end; by means of these retention ligatures the tendon ends are drawn together and then united by catgut sutures. Finally, the two retention ligatures are knotted together, and, if desired, the tendon sheath is sutured. Then follow drainage and closure of the cutaneous wound. It is sometimes difficult to find the central end of the tendon, which retracts to a greater or less extent, in consequence of the contraction of the muscle attached to it, and not infrequently the tendon sheath has to be opened for a long distance upwards—best on its lateral aspect—to find the central end. The longitudinal incision made through the skin for searching for the tendon stump should always be placed not over the tendon but to one side of it; this is the best way to avoid a subsequent adhesion of the tendon to the skin. To facilitate the finding of the central end of the tendon, it is also a good plan to explore its sheath with a sharp hook, with which the tendon may be seized and drawn out, or the extremity may be enveloped by an elastic bandage applied from the centre towards the periphery—the reverse of the usual manner of application. The muscle to which the tendon belongs may also be rubbed or pushed down from the outside. Very great difficulty sometimes attends the discovery of the central tendon stump in old cases of tendon division. The retraction of the central end, under these circumstances, is occasionally very considerable, and the above-mentioned methods for discovering the central stump of the tendon are not successful, because the stump is adherent

to the tendon sheath. Madelung has advised, in such cases, that the central end of the tendon be sought for by an incision located on the central side of the wound, or rather of the cicatrix, and that the tendon be freed and pushed towards the periphery with a round-headed probe, or, perhaps better, with a long, half-curved needle. For the same reasons mentioned before, it is better to make the longitudinal incision to one side of the tendon sheath. If the approximation of the two tendon stumps presents difficulties on account of the tension being too great, as may be the case when there has been a loss of substance, it is advisable to cut a flap with a pedicle from one or each of the tendon stumps. The ends of the tendon are split up to a point near the cut surfaces, and the pedunculated flaps thus formed which are still attached to the tendon are turned down into the defect and united with catgut sutures. Portions of tendons taken from young dogs or rabbits have been successfully engrafted in tendon defects, and attempts have been made to repair losses of substance by interposing strands of catgut (Gluck, Monod). But even in cases where the tendon ends could not be united but only drawn near one another, satisfactory results have been observed as regards the function of the muscle involved. In such cases, fibrous bands form between the tendon stumps, as in tenotomy, or the stumps sometimes become adherent to the skin, and the skin finally becomes so movable and extensible that it follows the movements, or rather traction, of the tendon. Duplay and Tillaux obtained a good result by suturing the peripheral end of the divided tendon of the extensor longus pollicis muscle (the cut ends were six centimetres apart, and hence could not be united) into a slit made in the underlying tendon of the extensor carpi radialis longior. Hager and others have likewise successfully united the peripheral tendon stump with the tendon of a neighbouring muscle having a similar action, when direct tenorrhaphy could not be carried out on account of too great a distance between the tendon stumps.

Tenoplasty for lengthening a Retracted (Shortened Tendon).—H. Sporon has devised the following means of lengthening a tendon which has become shortened by the repair of an injury of the tendon or from some other cause: After exposing the tendon by a longitudinal incision some five centimetres in length, two parallel longitudinal incisions of equal length are made in the long axis of the tendon, one placed one centimetre higher than the other. From the upper end of the higher incision and the lower end of the second, transverse incisions are made in opposite directions (Fig. 305). Thus the tendon, without being divided, can be lengthened an amount equal to the combined lengths of the two longitudinal incisions.

Suture of Muscles.—Transversely divided muscles are united by interrupted catgut sutures. In cases of loss of muscular substance—as when a piece is torn out of the continuity of the muscle—pedunculated flaps can be turned down into the defect and united by sutures, as in cases of defects in tendons.

Fig. 305. Lengthening of a tendon (Sporon).

Transplantation of Muscular Substance in Cases of Muscular Defects.—In cases of loss of substance in muscles, Gluck, Helferich and others have proposed the implantation of muscular tissue taken, for example, from a dog. According to the experiments of Magnus and Volkmann, a piece of muscle thus implanted always perishes, and is absorbed in the same way as an implanted portion of a nerve taken from an animal. As a general rule, therefore, one abstains from the transplantation of a portion of muscle in case of loss of muscular substance; it is unnecessary in small muscular defects, and even when the loss of substance is large the stump of the muscle can become connected by cicatricial tissue—a cicatricial *inscriptio tendinea*, as it were—and not suffer any loss of function. Fig. 306 shows very well that really extensive muscular defects may be so completely compensated for by cicatricial tissue, that the contraction of the muscle as a whole is not disturbed by the interposed cicatrix. Gluck has also attempted to remedy losses of muscular substance by the interposition of strands of catgut, as in defects in nerves and tendons.

Fig. 306.—Partial circular loss of substance in the muscles of the upper arm of a twenty-two-year-old factory girl, resulting from a gangrenous abscess which was caused in her fifth year by the bite of an insect; no disturbance of motion. (Uhde.)

Regeneration of Muscle.—It is well known that contractile muscular substance has but slight capabilities of regeneration. Muscular defects are always filled up by connective tissue, by cicatricial tissue, and not by new-formed contractile muscular fibres. But in the neighbourhood of the cicatrix, and in slight injuries and contusions of muscles, regenerative changes are observed which have been carefully studied by Weber, Waldeyer, Kraske, and others. At first an enlargement and proliferation of the nuclei of the muscle fibres takes place, and large, mono- and polynuclear cells appear, which take the place of the muscle fibres which have disappeared, and fill up the muscular interstices. These proliferated nuclei of the old muscle fibres are the formative cells of the new fibres; they arrange themselves into spindle-shaped cells lying side by side, in which very soon a fine longitudinal fibrillated stri-

ation is recognisable, and by the end of the third week the first traces of transverse striation make their appearance. Nauwerck, contrary to these teachings, which have been pretty generally accepted, was never able to prove that the proliferated new-formed muscular corpuscles changed into muscular fibres. According to Nauwerck, the new formation of muscular tissue takes place in the manner that E. Neumann described; it proceeds from the old muscular fibres by terminal and lateral budding, and by longitudinal cleavage and segmentation of the old and newly formed muscular fibres. The new-formed muscular fibres penetrate the cicatrix to a greater or less extent. The freer the process of repair is from reaction the more complete is the regeneration. Transplanted portions of muscle, as we have said, never retain their vitality; they perish without exception, and are subsequently absorbed. In their place a connective-tissue cicatrix forms, which possesses to a certain extent the function of muscle, like every other cicatrix in muscle.

Regeneration of Tendon Tissue.—The regeneration of tendon tissue after division of a tendon proceeds partly from the tendon sheath and partly from the stump of the tendon. After the lapse of two to three days vigorous proliferative changes and numerous caryocinetic figures are observed in the cells of the tendon sheath. The cells in the stumps of the tendon, which degenerate in part in the neighbourhood of the wound, likewise on the fourth to fifth day take a share in the healing process (Viering). By proliferation of the cells of the tendon sheath and those of the tendon proper there originates a granulation tissue, consisting of many-shaped cells, by which the tendon stumps are united. The granulation tissue then gradually changes into normal tendon tissue.

Neurorrhaphy. *The Union of Divided Nerves by Suture.*—There are two methods of performing nerve suture after a nerve has been divided, for instance, in an extremity: the *direct* nerve suture through the substance of the nerve itself, and the *indirect* or *paraneurotic* nerve suture through the connective tissue enclosing the nerve (Fig. 307). Both methods have yielded good results, especially since the introduction of antisepsis. The aseptic catgut suture is the most desirable for neurorrhaphy. The direct nerve suture is best performed as Wolberg has recommended—by passing a fine needle, flattened laterally, through the ends of the nerve about one centimetre from the cut surface, keeping the suture as superficial as possible and not passing it through the entire thickness of the nerve, so that the nerve fibres are damaged as little as possible. Two lateral sutures are more sparing of the nerve and hold it more securely than one suture through the middle of the nerve stump. According to observations hitherto made, *direct* nerve suture has never produced any

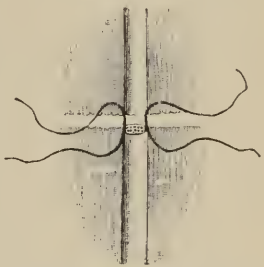


Fig. 307.—Nerve suture passed through paraneurotic connective-tissue.

bad effects. The *paraneurotic* suture passes, as we have said, entirely outside of the substance of the nerves themselves; one suture is applied laterally to the nerve through the paraneurotic connective tissue (Fig. 307), and then, if necessary, one is placed behind and another in front of the nerve, and thus the nerve stumps are indirectly brought into contact. I have found that a combination of both kinds of nerve suture is very advantageous, particularly in cases where there is some tension after the introduction of the sutures. The nerves are, however, so extensible and elastic that by exerting traction upon the central and peripheral stumps it is easy to do away with any tension.

Secondary Neurorrhaphy.—In *old* cases of divided nerves, "secondary neurorrhaphy" should always be performed. The operation has yielded very satisfactory results. Simon and Esmarch have successfully performed neurorrhaphy ten to sixteen months after the nerve has been divided, and in one case Jessop improved the paralytic symptoms by suturing the ulnar nerve nine years after the injury. In old cases of nerve division the stumps of the nerve are sought for, freed from the connective-tissue adhesions, and fresh surfaces made at the ends, which are then united by one or two aseptic catgut sutures.

Operative Treatment of Loss of Nerve Substance.—If there is a loss of nerve substance—a nerve defect—rendering it impossible to unite by sutures the widely separated ends of the nerve, various plans can be followed. In the first place, an attempt can be made to stretch the nerve by traction, so as to make it possible to unite the ends by sutures. If this cannot be done, i. e., if the nerve stumps cannot be brought sufficiently near together, flaps with pedicles may be formed from one or both ends of the nerve, turned down into the defect and united by catgut sutures (*autoplasie nerveuse à lambeaux Létiévant*). I practised this method successfully upon the median and ulnar nerves three months after the injury, and the paralysed right hand of the patient became so useful that she wrote me a letter of thanks a year after the operation. Dittel, Brenner and others have also had good results with this method.

Nerve-grafting.—Létiévant recommends *nerve-grafting* (*greffe nerveuse*) for loss of substance in nerves. The peripheral end of a divided nerve is united with an adjoining nerve by freshening the latter on one side and fastening the peripheral end of the injured nerve in the freshened area by means of catgut; or the peripheral end of the nerve is inserted between the fibres of the uninjured nerve. By the use of the latter method Déspres inserted the peripheral end of the median nerve between the fibres of the ulnar nerve, and the patient recovered the use of his hand. M. Gunn has experimented with the method upon animals with successful results.

Löbker's Procedure.—In a case of loss of substance in the flexor muscles of the forearm, involving the median and ulnar nerves, Löbker exsected a portion of bone subperiosteally from the radius and ulnar corresponding to the size of the defect, and then united by sutures the freshened stumps of the tendons and nerves.

Transplantation of a Portion of Nerve into a Nerve Defect.—The transplantation of a piece of one nerve into a nerve defect in another was first performed by Philippeaux and Vulpian. They were successful in causing a portion of the lingual nerve to heal into the hypoglossal. The latter completely regained its function. Recently Gluck has repeated these experiments, successfully implanting a portion of the sciatic nerve three centimetres long, taken from a dog, into a corresponding defect in the sciatic nerve of a rabbit. Eleven days after the operation the sciatic nerve in the rabbit is said to have become capable of conducting mechanical and electrical stimulation. This uncommonly rapid restoration of conductivity in a sutured nerve, and particularly in one which had been united by transplantation, contradicts all the observations hitherto made on this subject. In spite of the perfect union of the transplanted portion of nerve, Johnson, after twenty-three to twenty-four days, was unable to obtain a contraction of the muscles supplied by the nerve in question when he stimulated the latter with the induction current at a point central from the transplantation, but he did cause contractions by direct stimulation of the muscles. At all events, so rapid a restoration of nervous conductivity as Gluck describes, after the transplantation of pieces of nerve into nerve defects, can probably occur in only the most exceptional cases. As a general thing, the nerve fibres contained in the transplanted piece of nerve will perish; but they prevent connective tissue from growing into the nerve defect, and thus render it possible for the nerve fibrils which develop from the central end of the nerve to readily find their way to the peripheral end. Furthermore, it is my opinion that the nerve fibres in the above-described pedunculated nerve flaps do not persist; but the flaps prevent connective tissue from growing into the nerve defect, and in this way merely facilitate the bridging over of the nerve defect with newly formed nerve fibres. Vanlair has shown that losses of nerve substance—nerve defects—can be repaired by inserting the end of the nerve into an open decalcified bone drain or bone canal. By this means the ingrowth of connective tissue into the nerve defect is prevented, and the bridging over of the defect with newly formed nerve fibres is facilitated by the presence of the open canal. Gluck bridged over a defect five centimetres in length in the musculo-spiral nerve by means of a bundle of catgut; a year afterwards the function was entirely restored.

Corresponding to the gradual regeneration which takes place in the injured part of the nerve by the bridging of it over with newly formed nerve fibres, the conductivity of a nerve after it has been sutured only returns after the lapse of some time. Within some two to four weeks first sensibility returns in the affected skin area, and then motility, though in exceptional cases the improvement in sensation appears later than that in motion. The functional disturbance of the muscles gradually disappears as regeneration advances from the centre towards the periphery, and, as Etzold in particular has correctly stated, recovery takes place first of all in the parts which are nearest, while in those which are more distant it comes back much later and more incompletely, or these more distant parts may remain permanently paralysed. The return of motility is the only means of determining whether or not a neurorrhaphy has been successful in a nerve with motor and sensory fibres, inasmuch as sensation may become restored by means of the collateral branches of neighbouring nerves. From observations hitherto made, sixteen to nineteen days can be considered as the earliest period at which return of motility begins after a nerve suture; in other cases it began only after the lapse of several months, sometimes ten to twelve. But errors of observation are possible as regards improvement in motility after suturing a nerve, because here also, as we saw, the muscles which are not paralysed may take on the functions of those which are, and more or less compensate for the absence of activity in the really paralysed muscles. By making a careful electrical examination in such cases it is possible to determine whether or not the neurorrhaphy has been successful.

After-treatment of Tendon and Nerve Sutures.—The after-treatment of neurorrhaphies and tenorrhaphies consists principally in placing the affected portion of the body, when possible, in such a position that the suture is relaxed; for example, when the ulnar or median nerve has been sutured above the wrist joint the hand should be immobilised in a strongly flexed position by an antiseptic dressing, made possibly of curved wooden splints, or of a properly bent wire splint like that which Cramer advises. The remainder of the after-treatment following neurorrhaphy is very important, and consists in the use of electricity, massage, and methodical exercise of the affected muscles.

The Procedures when a Neurorrhaphy is Unsuccessful.—If a neurorrhaphy should partially or entirely fail, the cicatrix should be divided and the affected portion of the nerve examined, and, if possible, the neurorrhaphy should be repeated. In one case W. Busch exposed the affected part of the nerve ten months after an unsuccessful neurorrhaphy and found that the nerve at the point where it had been

sutured was encircled by connective tissue in such a way as to interrupt the conduction; he freed the nerve from the pressure of this connective-tissue cicatrix, and almost immediately the nerve became capable of conducting the induction current, and directly after the operation the patient could perform active movements which had previously been impossible. Likewise after fractures of the humerus W. Busch has seen two cases in which the musculo-spiral nerve was paralysed by the pressure of the callus, and in which the paralysis immediately disappeared after removal of this pressure. Both Socin and I have had similar experiences. As a matter of fact, it is well known that the conductivity of a nerve can be easily destroyed by pressure.

Spontaneous Regeneration of the Nerve without Suturing.—What clinical facts are there which bear upon the actual restoration of conductivity in nerves which have been divided and not united by suturing? The observations of Weir Mitchell, Morehaus, Keen and others prove that recovery takes place in exceptional cases after extensive injuries to nerves without the nerve stumps being united by sutures. Notta saw one instance of spontaneous regeneration within six months after division of all the nerves of the (upper) arm. Tiedemann, in August, 1827, exposed the brachial plexus of a dog in the axilla and divided each nerve, excising from them a piece two to two and a half centimetres long. Complete paralysis of sensation and motion followed in the affected extremity, but in the course of the years 1827 and 1828 sensation and motion returned entirely. In June, 1829, the dog was killed, and it was found that the ends of the nerves had been reunited by medullary nerve fibres. Schiff excised five centimetres of the vagus nerve in a dog, and after several months demonstrated restoration of the conductivity of the nerve without neurorrhaphy. Langenbeck and Hueter observed a restoration of conductivity after laceration of the brachial plexus in a Prussian officer who was wounded by a cannon ball in the storming of the Düppeler redoubt on April 18, 1864. The left lung was extensively injured, and the first rib was shattered, as was also a part of the scapula and clavicle. In spite of this severe injury the patient escaped with his life. Langenbeck again saw the patient in September of the same year, and his arm was totally paralysed. After the lapse of one year and a half the function of the arm was so far restored by electrical treatment that the patient became again fit for service, and served as an officer in the campaign of 1866. He was killed while battalion commander in the battle of Wörth. Riedinger, Krain, Létiévant and others have also observed recoveries after nerve division without neurorrhaphy. But all these recoveries are rare exceptions, and the ordinary termination is irreparable paralysis. This is due to the fact that the nerve fibres which have been cut off from their centres, as we remarked before, perish by fatty, granular degeneration, and with them the muscles they supply.

Results of Neurorrhaphy.—With the aid of my own and Wolberg's communications Weissenstein has collected seventy-six cases of neurorrhaphy, and he believes that the operation has been successful in sixty-seven per

cent. Amongst the seventy-six cases thirty-three were secondary neurorrhaphies, of which twenty-four were decidedly successful and others only partially so. The return of sensibility began, for the most part, after two to four weeks. The earliest return of motility began after sixteen days, but in the majority of the cases only after the lapse of months, and twice it required a year. In one case the paralysed muscles regained their complete usefulness after twenty-six days, though most of the cases took a year.

Regeneration after Complete Division of Nerves.—The regeneration of an injured nerve takes place essentially as follows: When a nerve has been completely divided, regeneration proceeds from the central end towards the periphery, and it takes place the more rapidly the less the interval between the central and peripheral nerve stumps, and hence most rapidly when the stumps are united by sutures. The newly developed nerve fibres spring from the central stump of the old nerve, and, bridging over the defect, unite with the peripheral stump. According to one view, the old nerve fibres of the peripheral segment, after their separation from the centre, perish irrevocably, and the newly formed nerve fibres from the central end grow, analogously to what takes place in embryonic development, along the peripheral stump into the muscles and skin (Vanlair). According to another view, the fibres of the peripheral stump do degenerate, but after the regenerated central fibres have entered the peripheral stump its fibres likewise take part in the regeneration and unite with the fibres, growing out towards them from the central end. Both kinds of regeneration may occur at the same time, and the regeneration of the degenerated fibres in the peripheral stump will take place the more rapidly the earlier the central and peripheral ends are united by sutures. After division of a nerve in man there has never yet been observed a direct union of the divided nerve-fibres, a so-called *prima reunio*, with restoration of conductivity within seventy to eighty to ninety hours, as Gluck has observed it in animal experimentation. After the lapse of about two to three months, sometimes later, the regeneration of, for instance, a large nerve in an extremity, is usually completed. If the nerve stumps are not united by suture, and if the distance between the central and peripheral stumps is too great, usually no regeneration of the nerve defect occurs. Under these conditions the central end of the nerve takes on a club-shaped enlargement from the formation of new nerve fibres and new connective tissue. This represents an attempt at regeneration. The so-called amputation neuromata are also examples of such club-shaped enlargements of the ends of the divided nerves. In the most rare and exceptional instances large nerve defects, up to five centimetres in extent, have been restored in man and animals without the nerve being sutured. But, as a general thing, the experiments of Sticker and others show that spontaneous regeneration of the nerve fails when the distance between the nerve stumps amounts to one centimetre.

Regeneration after Incomplete Division of the Nerve.—In incomplete division of a nerve, in contusions, etc., regeneration usually takes place more rapidly. If the conductivity of the nerve has been interrupted by compression, such as would be exerted by a bony tumour, by a callus, etc., immediate restoration of the power of conducting a nerve current has been observed upon relieving the pressure. A regeneration of the tissues of the brain and

spinal cord never takes place in man. But Brown-Séquard has observed a regeneration of a divided spinal cord in doves.

With the regeneration of the nerves the excitability of the latter also returns, and, according to Erb, Ziemssen, and others, the power of conduction returns sooner than the local excitability; that is, muscular contractions will at first only occur when stimulation is applied above the point of injury, and not when applied below.

Histological Changes in Nerve Regeneration.—Opinions vary as to the changes which occur in the regeneration of a nerve. In all cases the regeneration begins in the central end. About the third week, small, pale processes are seen projecting from the axis cylinders—i. e., the proximal axis cylinders become prolonged; they grow outwards, and at the same time divide into two or more filaments. These newly formed nerve filaments become longer and longer, and, according to the investigations of Vanlair and others, they grow into the skin and muscles. The young nerve fibres, according to the views of various authorities, are at the outset naked axis cylinders, and then subsequently become covered by the sheath of Schwann. The statements made by some authors, that the young nerve fibres are formed from connective-tissue cells or colourless blood-corpuscles, contradict all our other histogenetic views. According to Büngner, the regeneration of the injured nerves *proceeds from the nuclei and the protoplasm of the sheath of Schwann. They are to be regarded as the true neuroblasts.*

According to the investigations of many authorities, as we have said, analogous regenerative changes in the degenerated fibres also take place in the peripheral nerve stump, but much later than in the central stump. The newly developed central and peripheral nerve fibres grow towards each other and unite. The regenerative changes in the old degenerated fibres in the peripheral nerve segment are disputed by some observers, as we have remarked. As a matter of fact, it is very difficult to distinguish histologically the regeneration and degeneration which go on side by side in the peripheral nerve stump. Mayer has made the important observation that regenerative and degenerative changes occur even in perfectly normal nerves.

Only those fibres which remain connected with their centres are capable of regenerating themselves. The so-called *régénération autogénique*, long insisted upon by Vulpian—that is, the independent regeneration of a portion of nerve cut off from its centre—is founded upon an error, as Vulpian himself has admitted.

The works treating of nerve regeneration are very numerous. Cruikshank, experimenting on animals, was the first to observe, in 1776, complete regeneration of divided nerves. References to the most important literature on the subjects of nerve injuries and neurorrhaphy will be found in a paper on these matters in the Archiv für klin. Chir., Bd. xxvii.

Further Treatment of Wounds of Soft Parts.—The further treatment of wounds of soft parts consists in the most careful *disinfection* of the wound and in the removal of any foreign body which has entered it, such as sand, dirt of every description, pieces of glass, points of instruments, bullets, etc. By using Esmarch's artificial ischæmia the

search for foreign bodies will be greatly facilitated. We shall return to the extraction of bullets in the chapter on Gunshot Wounds. The removal of foreign bodies from the internal organs and the large cavities of the body is discussed in the Special Surgery.

When the treatment of the wound has been carried out in the manner described, we then proceed, in the case of large, deep wounds, to provide for drainage for carrying off the wound secretion (§ 31). After this, in proper cases, the wound is closed by sutures (§ 33), and an antiseptic dressing is applied (§ § 44 – 49). All fresh wounds which are not infected or markedly contused are suitable for suturing. If there is much contusion of the parts, sutures should be avoided, especially on the skull, where, after deficient antisepsis, a retention of the secretion from the wound may so easily become dangerous and lead to suppurative phlebitis with secondary fatal meningitis. If the contusion is limited simply to the borders of the wound they can be excised and the wound then closed by sutures. In all cases where there is doubt about the propriety of suturing the wound, it is preferable to omit it entirely or to suture only partially—for example, in the middle of the wound.

Indications for Amputation or Disarticulation.—Amputation or disarticulation is indicated in fresh cases if the soft parts are so crushed and disintegrated that either the repair of the injury is impossible, or, if it should occur, the injured limb would be completely useless. Amputation is also indicated in cases with septic cellulitis, in order to prevent death from sepsis. When amputation has to be performed for fresh lacerated and contused wounds, it should only be carried out in sound, normal tissues, and not within the limits of the contusion. In general, operations should be as conservative as possible, especially those upon the fingers. If all the fingers have to be removed and the thumb only can be saved, this should be done in every case, as a movable thumb is better than an entire artificial hand. In the tearing away of extremities or of parts of them, disarticulations, amputations, or plastic operations are also necessary for improving the stump or for hastening recovery. A stump of bone projecting from the soft parts, after the latter have been torn from the phalanges of the fingers, must always be excised or disarticulated by the saw, chisel, or bone forceps at a point where it will be covered by soft parts.

Dressings, packing the Wound, etc.—The protective dressings employed for superficial cutaneous wounds and for all small wounds consist of English sticking-plaster, adhesive-plaster gauze, adhesive plaster, strips of mull with collodion, etc. Superficial abrasions of the skin are covered with iodoform collodion (1 to 10). The dressing with English

sticking-plaster can be made to adhere by painting it over with collodion. Small uninfected wounds closed by a crust of blood, etc., will heal under the scab without a dressing. As we saw in § § 44 – 47, the number of antiseptic dressings is very great. It is especially advantageous to cover the wound with sterilised gauze, and over the latter to place aseptic cotton. Dusting-powders, like iodoform, dermatol, bismuth, oxide of zinc, etc., are better suited for unsutured contused wounds. Packing with aseptic gauze or iodoform gauze is particularly applicable for large contused and lacerated wounds, with or without injury to bones, joints, etc. After removal of the aseptic packing the wound can be closed by secondary sutures, or the packing may be left to dry and form a firm aseptic scab upon the wound until it falls off of its own accord. In suitable cases—for example, in extensive contused wounds—antiseptic irrigation (§ 49) should be employed. Under certain conditions it is an excellent plan to place the patient in a permanent water-bath (§ 49).

I must refer the reader to § 22 and § 62 for the treatment of the general condition of those who have been injured.

Treatment of Secondary Hæmorrhage.—Any secondary hæmorrhages which occur during the healing of the wound are to be arrested, if in an extremity, by double ligation of the vessel in the wound with the assistance of Esmarch's bandage. The ligation of the principal artery in its continuity above the wound, at the so-called place of election, is only to be recommended when the application of Esmarch's bandage is impossible and the blood wells out from the depths of the wound in such amounts that there is danger of the patient's bleeding to death. In such critical conditions an assistant should stop the hæmorrhage by pressure with the finger in the wound while the main artery is rapidly secured at some easily accessible, centrally situated point. The wound can then be examined more leisurely and the injured vessel tied in the wound by a double ligature. The leaving in place of artery forceps, a firm packing of the wound with iodoform gauze, dressings which exert pressure, digital compression, etc. (§ § 28 and 29), have also rendered excellent service in cases of secondary hæmorrhage from deeply located regions, where the application of a ligature is impossible or difficult.

Suppuration—Burrowing of Pus.—During the healing of the wound, especially if it is a large contused or suppurating wound, one must always guard against any burrowing of pus. If spreading inflammation and suppuration are already present in the wound when it comes under observation, as many incisions as are required should be made, as described in § 70 (cellulitis). The treatment of complications of

infected wounds, including the infectious-wound diseases, is discussed in § § 62–82.

Every wound until it has cicatrised should be treated strictly according to antiseptic rules; these should never be neglected, especially during a change of dressings. In the later stages of repair in the wound, especially when it is granulating, ointment dressings are to be employed (§ 49). The final skinning over of a granulating wound is often hastened by the occasional use of the nitrate of silver stick. By this cauterisation with argent. nitrat., we make the shrinkage of the granulation tissue more rapid and prevent it from growing too luxuriantly. We cover extensive losses of substance in the skin with transplanted skin (§ 42), or by plastic operations (§ 41), etc. The formation of cicatricial contractures is always, as far as possible, to be prevented; but if contractures do nevertheless develop, they should be treated in the manner described on pages 140, 299, 487, and in § 119.

For finding metallic foreign bodies which have become healed up in a wound the magnetic needle has been used with success. By its deviations it can indicate, for example, the location of a needle which has become healed up in the wound (Kocher, etc.). Also for finding bullets which have healed in, the magnetic needle can be used with advantage, particularly in army surgery (see § 124).

§ 89. **Treatment of the Conditions Following Severe Hæmorrhages—Blood and Common Salt Infusion.**—If, after an injury to large arteries or veins, the hæmorrhage has been considerable, the general weak condition of the patient very often demands, after arrest of the bleeding, the adoption of special measures which must be carried out rapidly and energetically. In the milder cases of swooning after loss of blood, the head should be placed as low as possible, the face of the patient sprinkled with water, olfactory stimulants, such as ammonia, administered, as well as several hypodermic injections of ether; the patient should be placed as soon as possible under warm coverings and surrounded by hot bottles, sand-bags, and the like, besides being rubbed with towels and stimulated with strong wine, cognac, black coffee, etc. It is also a very excellent plan to supply a patient who has lost a large amount of blood with great quantities of heated fluids; they are absorbed from the gastro-intestinal tract more rapidly than under normal conditions, and are a direct means of making good the blood deficiency. In severe cases the lowering of the head should be combined with elevation of the legs, or, better, with the envelopment of the legs in an elastic bandage, in order to prevent the threatening cerebral anæmia and to drive the blood out of the extremities towards the heart, the lungs, and the brain (autotransfusion). In the cases of very extreme

anæmia all the above-mentioned remedies will be of no avail in keeping the patient alive, and the only other remedy that offers any hope is the transfusion or infusion of blood or a sterilised physiological solution of sodium chloride.

Transfusion of Blood used to be very frequently practised for threatening death from hæmorrhage, for poisoning by illuminating gas, carbonic oxide, carbonic acid, for septicæmia, and for various internal diseases. At present the belief in the capabilities of transfusion has been given up, and the operation is but rarely performed. With the increasing knowledge of the physiology and pathology of the blood, we have found that the earlier views and presumptions which lay at the foundation of blood transfusion were false. I fully agree with Bergmann and others who, reasoning from physiological facts, consider transfusion not only a useless, but also, as we shall see, a dangerous operation.

Causes of Death from Hæmorrhage.—The cause of death from hæmorrhage used to be ascribed to the loss of red blood-corpuscles, and hence to the impoverishment of the blood in hæmoglobin, or rather in oxygen. But now we know that death from hæmorrhage is dependent upon purely mechanical conditions. It is caused by the insufficient filling of the vascular system, by the fall of the arterial blood pressure, or, in other words, by the purely mechanical disproportion between the capacity of the vascular system and the amount of its contents. For this reason the movement of the contents of the vessels ceases; the heart, which at first continues to beat, is, like an empty pump, no longer able to raise the column of blood and drive it onwards. Hence in such cases the indication is to increase the contents of the vascular system by infusion of some liquid, and for this purpose the blood of man or animals, in its entirety, or defibrinated human blood, used to be employed; but recently the infusion of an alkaline seven-tenths per-cent. solution of common salt has been largely substituted for blood transfusion (Kronecker, Sander, etc.).

Infusion of a Common Salt Solution.—As a matter of fact, infusion of common salt is better than blood transfusion, and I should always use it in cases of acute anæmia. The recent reports of Cavazzani, Porstempski, and others, which favour blood transfusion, do not influence my views in the least. Landerer, at the suggestion of C. Ludwig and Gaule, has proposed the addition of three to five per cent. of sugar to the alkaline (0·7 per cent.) solution of common salt. The advantage of the salt-sugar solution over the plain salt solution consists, according to Ludwig, in the fact that the former is to be regarded as a nutritive solution, and that, in consequence of its high endosmotic equivalent, blood

which contains sugar takes up the parenchymatous fluids more energetically; moreover, the blood pressure rises more rapidly, and the red blood-corpuscles are more apt to remain intact than when a pure salt solution is employed. It is simplest to infuse the salt solution subcutaneously (pages 483, 484.)

Dangers of Blood Transfusion.—That the transfusion of blood in any form is not only a useless but also a dangerous operation, the following statements prove. In the first place, we know from the experiments made by Müller and Lesser, under the guidance of C. Ludwig, that all the red blood-corpuscles injected with the blood are destroyed in a few days. The corresponding hæmoglobinuria which accompanies this process is caused by the disintegration of the red corpuscles, or, rather, by the separation of the hæmoglobin from the stroma of the red corpuscles, allowing free hæmoglobin to circulate in the blood. According to Sachsendahl, the dissolved hæmoglobin is the most powerful agent for bringing about a rapid destruction of the colourless blood-corpuscles and a very sudden and marked accumulation of the fibrin ferment in the circulating blood, so that death may occur from ferment intoxication.

Magendie uttered a warning against the use of defibrinated blood, because its injection was followed by very definite disorders, such as rapid respiration, diarrhœa, bloody transudations into the peritonæum, the pleura and pericardium, and even by death. The interesting investigations of Armin Köhler show the possibility of ferment intoxication after blood transfusion. He demonstrated that blood taken from another species, as well as blood from the same species, had a poisonous action. If only ten to twelve cubic centimetres of blood were drawn from the carotid of a strong rabbit, allowed to coagulate, and the blood coagulum then chopped up, pressed between pieces of linen, filtered, and of this defibrinated blood only five to six cubic centimetres were injected slowly into the internal jugular vein of the same animal, it usually died during the injection, from extensive coagulation in the right heart and in all the branches of the pulmonary artery in both lungs. These facts are explainable upon Schmidt's theory of coagulation. The fibrino-plastic substance, and particularly the fibrin ferment, are found free in blood defibrinated in the above manner, and being carried in this state into the circulating blood they excite within the blood channels extensive thromboses. The animal dies in consequence of the ferment intoxication. *Pepsin* and *pancreatin* have an effect analogous to the blood ferment (Bergmann, Angerer). Blood defibrinated by beating or shaking, according to the old method of blood transfusion, is not by any means as rich in the fibrino-plastic substance and in the fibrin ferment as blood which has been pressed in the manner just described, but it is only a difference in quantity; consequently Köhler is right in considering blood which has been defibrinated by whipping not so harmless as has been hitherto supposed. As regards the histocym isolated from the blood by Schmiedeberg, see page 307.

Transfusion of Animal Blood.—In the transfusion of blood taken from another species of animal still other conditions come into consideration. Partly as a result of chemical action and partly as a result of the above-

mentioned disintegration of the red blood-corpuscles, the blood of a sheep, for example, is a fatal poison for a dog if injected in sufficient amount into the vascular system of the latter ; and again, a dog's blood is just as poisonous for a sheep. After the direct introduction of lamb's or dog's blood into the veins of a man, dangerous symptoms had been observed more than two hundred years ago, and yet about fourteen years ago an attempt was made to reintroduce the transfusion into man of lamb's blood. Chills, fever, hæmoglobinuria, as a result of the disintegration of the red corpuscles in the circulating blood, and not infrequently death, were the consequences. Panum, Landois and Ponfick have proved by numerous experiments the dangers of the transfusion of animal blood into man, and, in fact, the danger of transfusion of blood in any form which has been taken from another species. We shall now always be on our guard against a return to the transfusion of animal blood.

Direct Blood Transfusion.—It would be most advantageous if the blood in its entirety could be conducted from the artery of a man into the vein of the receiver. But all kinds of difficulties stand in the way of employing this *direct* transfusion. It is not so easy to find any one who will give blood directly from an artery as one who will give it from a vein. Then, the possibility of the blood coagulating in the conducting tube must be taken into consideration. Furthermore, it is always questionable whether the corpuscles retain their vitality in the blood of the receiver.

Wright and Hertig have recommended decalcified blood for transfusion, as Arthus and Pagés found that it did not coagulate (see page 293).

As a substitute for the introduction of blood into the vascular system, Ponfick has recommended intra-peritoneal transfusion—i. e., the infusion of defibrinated blood into the peritoneal cavity. The clinical and experimental investigations of Angerer, Edelberg and others have taught that this method should be condemned.

Ziemssen has employed with advantage in chronic anæmia the subcutaneous injection of defibrinated blood at a temperature of 37° to 40° C. into the subcutaneous tissue of the thigh, using, for example, three hundred and fifty grains in about fourteen injections. For acute anæmia Ziemssen and others recommend the subcutaneous injection of a sterilised, physiological, seven-tenths per-cent. solution of common salt.

Indications for Infusion of Blood and Sodium Chloride.—The indications for undertaking blood or common-salt infusion are most frequently a high grade of anæmia after loss of blood, and poisoning by, for example, carbonic-oxide gas and illuminating gas, in which common salt infusion has also repeatedly proved efficacious. The operation is no longer employed for septicæmia or chronic diseases of the blood (chlorosis, leucocythæmia, pernicious anæmia, etc.), nor for chronic marasmus.

General Technique of Blood and Common Salt Infusion.—The transfusion is carried out without an anæsthetic, in order that the behaviour of the patient during the infusion can be more accurately observed. The operation is not painful, and very often the patients are unconscious. During the transfusion of blood a greater or less amount of dyspnœa and cyanosis is usually observed, and both manifestations not infrequently become so pronounced that the operation has to be suspended. Furthermore, if fainting-fits supervene, the infusion should be immediately stopped.

Technique of the Transfusion of Venous Blood.—In venous transfusion with defibrinated human blood, about two hundred to four hundred grammes of blood are drawn from a vein of a strong man into a carefully disinfected glass vessel. The blood is heated on a water bath to about 39° to 40° C. (102·2° to 104° F.), defibrinated by whipping with a clean glass rod, then filtered through clean linen in a glass funnel into another glass vessel kept at about 39° to 40° C. (102·2° to 104° F.) over a water bath. While an assistant attends to the defibrination and filtration of the blood, a large cutaneous vein —usually at the elbow—is picked out. The finding of the vein can be facilitated by causing it to become distended with a phlebotomy bandage wound around the (upper) arm. After exposing the vein and isolating some 2·3 centimetres of its extent, two catgut ligatures are passed under it, and the vein is gently lifted with the peripheral ligature and opened by scissors. A disinfected glass cannula is pushed into the opened vein in the direction of the blood current and secured by the other ligature. The bleeding from the vein is checked simply by lifting the vein by the peripheral ligature, or the latter may be knotted. The glass cannula is filled with blood, and then the warm defibrinated blood is injected by a glass syringe, which is not too large, or a glass jar is used with a rubber tube like an irrigator. About two hundred to three hundred grammes are injected slowly ; Hueter recommends the injection of four hundred grammes or more. The entrance of air into the vein and the formation of coagula are especially to be avoided. The strictest asepsis as regards the giver and receiver of the blood must always be observed.

Technique of Arterial Blood Transfusion.—In arterial transfusion (Gräfe, Hueter) the radial or ulnar artery is exposed and sufficiently isolated above the wrist joint. Three catgut ligatures are then pushed under the artery. The centrally located ligature is knotted and occludes the artery, while a simple knot or sling is made with the peripheral ligature, or the vessel is closed temporarily with a small artery clamp. The artery is then opened with scissors between the two ligatures or on the proximal side of the peripherally placed artery clamp, a glass tube is pushed into the hole in the artery towards the periphery and firmly secured with the third ligature. The further course of the operation is the same as above.

After the termination of the transfusion the artery and vein are tied centrally and peripherally, the intervening portion used for the infusion is extirpated, and the glass cannula removed. Hueter claims that the advantage of arterial transfusion lies in the fact that the blood is first driven into the capillaries, and the latter act as a filter for any clot that may be injected; there is, moreover, no danger of the entrance of air.

Technique of Direct Blood Transfusion.—In the direct conduction of blood from an artery into a vein the above rules are followed—i. e., a glass cannula is tied into the vein of the receiver and one into the artery of the giver of the blood, and both are connected by a rigorously disinfected rubber tube in which a glass tube is sometimes interposed to control any coagulation.

Technique of Sodium-Chloride Infusion.—In the sodium-chloride infusion, which should be undertaken as soon as possible after the hæmorrhage and with the strictest asepsis, a sterilised seven-tenths-per-cent. solution of common salt warmed to about 39° C. (102·2° F.) is used, which is rendered alka-

line by the addition of sodium hydroxide or potassium carbonate. Szuman recommends aq. destil. 1,000, sod. chlorat. 6·0, sod. carb. 1·0. For one to one and a half litres of a seven-tenths-per-cent. solution of common salt about three drops of sodium hydrate are sufficient. According to Kronecker, the solution of salt should be 0·73 per cent. and *neutral*—alkaline liquids may prove dangerous—or the above-mentioned salt-sugar solution of Ludwig's may be used. For infusion, a glass funnel is employed, or a glass flask with a tube at the bottom connecting it with a rubber tube and a glass cannula. The infusion should take place under no higher pressure than exists in the large veins. Jacobson states that this is represented at the most by one centimetre of mercury or thirteen centimetres of the sodium-chloride solution—i. e., the infusion flask should not be held higher than 0·13 to 0·25 millimetre above the opening in the vein. During the infusion the body, especially the abdominal viscera, should be vigorously massaged. Five hundred cubic centimetres at the least are injected, and in severe cases of hæmorrhage about one thousand to fifteen hundred cubic centimetres. The infusion should not be carried on too rapidly, about sixty to ninety cubic centimetres being injected in a minute. The success of sodium-chloride infusion has so far been very encouraging. The *venous* salt infusion, according to the experience we have had with it, should be preferred to the *arterial*. The arterial salt infusion has also been made into the central end of an artery, the radial, for example; but this method has no advantage over the venous infusion.

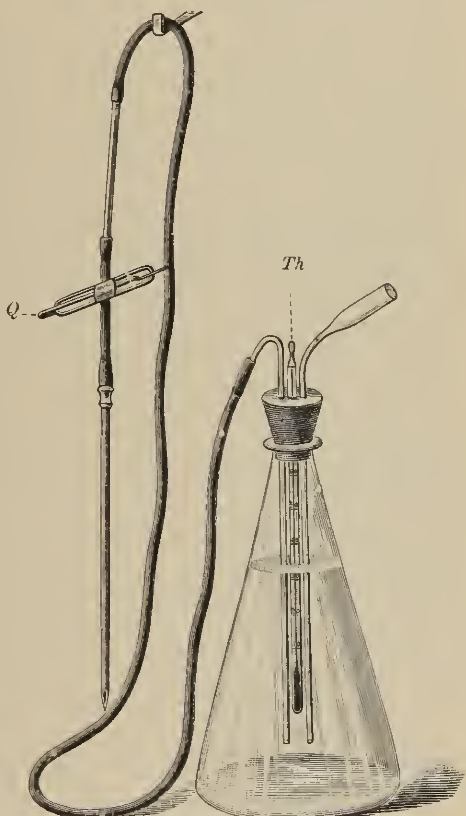


Fig. 308.—Apparatus for the transfusion of a saline solution, consisting of a glass vessel with a rubber stopper having three holes; a thermometer (*Th*), a rubber tube with an interposed glass tube, a stop-cock (*Q*), and a hollow needle.

Kümmel likewise warns against infusing salt solution into an *artery*. After the infusion with a glass syringe of about five hundred grammes of a six-tenths-per-cent. alkaline salt solution into the radial artery, gangrene of the skin followed, rendering it necessary to amputate the forearm between the lower and middle thirds.

Subcutaneous Salt Infusion.—According to my own experience, the subcu-

taneous infusion of a sterilised seven-tenths-per-cent. solution of common salt is exceedingly good. The investigations of Ziemssen, Samuel, etc., have demonstrated that the system, even when the activity of the heart is impaired, is still able to take up into its circulation great quantities of salt solution injected subcutaneously. It is injected through a hollow needle into various parts of the body, particularly beneath the skin over the abdomen, by means of some apparatus like that of Sahli's, illustrated in Fig. 308; five hundred to one thousand cubic centimetres, warmed to 39° C. (102·2° F.), are injected during five to ten to fifteen to twenty to thirty minutes, according to the nature of the case, and absorption is hastened by gentle rubbing (massage). I have seen remarkable results in acute anæmia, and in collapse after prolonged operations on weak individuals. In proper cases several litres of salt solution can be injected subcutaneously on several different days. In one patient with chronic mercurial poisoning, Sahli washed out the body, as it were, with twenty-one litres of salt solution in eight sittings; each time two and a half to four litres were infused subcutaneously. However, a therapeutic success was not obtained, since the mercury could not be demonstrated in the urine.*

Infusion of Warm Water.—In one case Coates made a successful injection of six hundred and fifty grammes of pure warm water into the cephalic vein.

Milk Infusion.—At the end of the eighteenth century Muralto recommended the injection of milk instead of blood. American physicians in particular are said to have used milk infusions into the veins with success. But Landois and others have shown by animal experimentation that the procedure is to be condemned as directly dangerous to life; its results are marked disturbances of circulation, coagulations, and emboli. Vigezzi has recently tested experimentally the infusion of milk into veins, and he states that acidified milk brings about the above-mentioned dangerous manifestations, but that milk mixed with an alkaline solution is entirely harmless.

§ 90. **Burns.**—Burns originate in a great many different ways—e. g., by direct contact of the affected portion of the body with a flame, or by the explosion of powder, illuminating gas, "fire-damp," etc. Fire-damp occurs in coal mines in particular, and causes an explosion if mixed with a double volume of oxygen or a tenfold volume of air and brought in contact with a flame. Burns are very often due to the action of hot gases, steam, liquids, hot solid bodies, such as metals, etc. In this class of cases belong the injuries caused by caustic substances such as concentrated acids (sulphuric acid, nitric acid, etc.), and by caustic alkalies. Comparatively mild burns of the skin are caused by the sun's rays.

Symptoms and Course of Burns.—The clinical course of a burn depends upon its intensity and extent. The intensity of the burn is conditional upon the degree of the heat and the duration of its action. The purely local manifestations may occur in three different degrees of

* Sahli, Samml. klin. Vortr., N. F., No. 11.

severity: First degree, *hyperæmia;* second degree, *bleb formation;* third degree, *eschar formation.*

Burns of the First Degree.—*The first degree* is characterised by a painful redness and slight swelling of the skin—i. e., by a dilatation of the capillaries, with a slight exudation of serum, as in erythema, or in a mild inflammation. In the mildest cases the redness disappears in a short time and nothing follows. Very frequently the horny layer of epidermis is cast off in the form of small scales or patches. In the *second degree* of burn we observe, in addition to the manifestations of the first degree, the development of small and large *blebs*, which are filled with a watery, transparent, or slightly yellow serum, and here and there with serum mixed with blood. These blebs either develop immediately or in the course of the next few hours after the reception of the burn. The blebs are usually located in the epidermis, and their contents raise the horny layer from the underlying layer of the rete Malpighii. The rapid development of the blebs in a burn has not yet been clearly explained. In burns of this second degree the swelling and pain are usually very considerable, especially at those points where there is much tension, or when the blebs are removed and the very sensitive reddened corium is exposed to the air. If the blebs break or are artificially opened, the epidermis beneath the portion that has been lifted up forms a new horny layer within three to six to eight days, and from this the shreds of the old horny layer can be easily removed. If the true cutis is exposed, or if the latter is involved in the burn, suppuration often ensues; but it can be entirely prevented by antiseptic dressings, after previously carefully disinfecting the parts. These latter cases form the transition to burns of the *third degree*, in which, as a result of the action of very severe heat, an *eschar* is formed. The appearance of the eschar varies greatly, being ashy grey, brown, yellow or black in colour, and either moist or dry. The separation of the eschar is brought about by the ensuing suppuration, which can be limited or prevented by antiseptic treatment. In burns of the third degree the difference between individual cases is very great, and they include burns varying from a partial destruction of the cutis to a complete carbonisation of an entire extremity. Hence

Fig. 309.—Cicatrix resulting from a burn with boiling water, observed in a boy five years old.

it follows that the division of burns into three degrees is somewhat illusory, and there have been surgeons who have distinguished seven to ten degrees of burns. But the division of burns into three degrees is, on the whole, the best.

The casting off of the burned tissue occasionally takes a very long time, especially when bones are involved. When the eschar has been removed, and a correspondingly large granulating wound surface has taken its place, the skin gradually forms over it, as described in § 61. A very extensive destruction of skin is often observed after burns, causing great obstacles to repair. The cicatrix not infrequently gives rise to various disturbances of function and to deformities, amongst which mention should be made of ectropion of the eyelids, adhesion of the chin to the chest, contractures of joints in the extremities, etc. (Fig. 309). These cicatricial contractures are best prevented by the transplantation of large, fresh cutaneous flaps with pedicles, or by skin grafting.

Constitutional Symptoms after a Burn.—The constitutional symptoms observed after the reception of a burn depend in the first place upon the extent of the burn. It is generally accepted that when more than half the surface of the body is burned even to a slight extent death is certain to follow; in many cases death ensues when the burn involves only a third of the body. The carbonisation of an extremity is, in general, better borne than an extensive slight burn of the surface of the body. After extensive burns death ensues either immediately after the injury or in the course of the first or second day, or after several days or weeks—i. e., either in the stage of inflammatory reaction, or in that of suppuration and exhaustion.

Immediately after the reception of an extensive burn the patient is usually in a state of great excitement, he complains of severe pain in the injured part, and often cries and screams. The mind is at first entirely clear. In the cases running a rapidly fatal course the patients are very restless and toss about in bed; delirium and cramps come on, the thready pulse is extremely rapid, the temperature of the body is below normal—sometimes as much as 3° to 5° F.—the respiration is superficial and rapid, the extremities are cool, and death usually follows with increasing symptoms of collapse and coma. The lowering of the temperature occurring, as a rule, in extensive burns of the skin is due to the abnormally increased radiation of heat from the dilated vessels in the affected parts which have been robbed of their protecting epidermic covering. In a number of cases of burns very pronounced excitement is present until shortly before death, while other patients lie quietly in a state of apathy. There is often vomiting and great thirst. The

urine, in the majority of instances, is very scanty, and occasionally there may be more or less complete anuria, and not infrequently hæmoglobinuria. The latter is a result of the destruction of the red blood-corpuscles which were in the vessels of the affected part at the time of the burning. If the patient survives the first two days much has been gained, but after the lapse of five to six days, in the stage of the inflammatory reaction, the above-described group of symptoms may suddenly make their appearance and cause death within a few hours. In the later stages the cause of death is due essentially, as we have said, to the increasing exhaustion; a violent diarrhœa begins, with now and then the formation of ulcers in the duodenum, usually in the neighbourhood of the pylorus.

Causes of Death after Extensive Burns.—How is the death which quickly ensues after extensive burns to be explained? The opinions of various authorities differ greatly upon this subject, and as yet no generally satisfactory explanation has been advanced. According to Wertheim, Ponfick, and others, the above-mentioned destruction of the red blood-corpuscles is the main cause of death. The marked diminution in the number of red blood-corpuscles which are necessary for respiration and for metabolism, produces, according to this view, death, with symptoms similar to those in carbonic-acid-gas poisoning; or the sudden death of the red blood-corpuscles has in itself a deleterious effect. In consequence of the destruction of the red cells, the hæmoglobin is dissolved in the blood, and this, as we know, is also a means of rapidly destroying the white blood-corpuscles, and of favouring the development of the fibrin ferment, and of extensive coagula in the vessels. As a matter of fact, extensive thrombi, originating *intra vitam*, are found in the vessels of all the different organs; this has been recently demonstrated in man and animals by Silbermann and Welti. Furthermore, larger or smaller amounts of hæmoglobin are frequently found in the kidneys, it being most plentiful in the straight uriniferous tubules, though occurring also in the convoluted tubules and within Bowman's capsule. From the presence of hæmoglobin such kidneys have a dark, brownish-red colour, which used to be erroneously ascribed to excessive hyperæmia. In addition, the kidneys are more or less hyperæmic, and, like the stomach and liver, full of necrotic foci. These necroses become more extensive with the prolongation of life after the reception of the burn (Welti). The diminished excretion of urine is explained by the changes in the kidneys. Reasoning from his experiments and observations, Sonnenburg has come to the conclusion that death after extensive burns is caused either by the overheating of the blood with subsequent cardiac paralysis (in such cases it immediately follows the injury), or that the characteristic manifestations of collapse are to be regarded as the effect of an excessive irritation of the nervous system, which has, as its reflex result, a lowering of the tone of the vessels. The hyperæmia and ecchymoses of the internal organs so frequently found in autopsies upon people who have been burned, Sonnenburg ascribes to the diminution of the vascular tone which has been brought about reflexly.

According to Salvioli, the cause of death from burns is to be sought for mainly in the formation of numerous thrombi and emboli made up of blood-plaques. In consequence of these blood-plaque thrombi, and in consequence of the increased adhesiveness of the blood-corpuscles, the circulation finally comes to a complete stand-still. After animals have been, as far as possible, deprived of the blood-plaques by venesection and injection of defibrinated blood, they endure severe burns much better, for the reason that the above-mentioned thrombi do not develop.

According to Lustgarten, death from burning is due to ptomaine poisoning. The intoxication is caused by the metabolic products of the organisms of decomposition which, lying in the depths of the cutaneous follicles, have escaped the effects of the burn.

The other theories about the causes of death after extensive burns lack a foundation in fact, and have found but few adherents. I will mention only *the stoppage of the activity of the skin as a result of extensive burns, the accumulation in the blood of certain poisonous substances like ammonia* (*ammonœmia*), *and the loss of blood serum with the consequent thickening of the blood.*

Recently Catiano has again adopted the theory that death after extensive burns is caused by *noxious chemical substances.* He has raised the question whether, in extensive burns, a substance found mostly in the skin is not changed, by being rapidly heated, into a poison, the absorption of which gives rise to the disturbances in question. The sweat of the skin has an acid reaction from formic acid (CH_2O_2). If this is gradually neutralised on the skin by ammonium hydroxide there forms the very easily soluble formate of ammonium. If this salt is rapidly heated it loses water and changes into *hydrocyanic acid.* The symptoms of hydrocyanic-acid poisoning are said to be in every respect similar to those following burns.

The causes of death in the later stages of the inflammatory reaction, as well as during the period of suppuration and exhaustion, vary greatly in their nature. The intensity of the burn and the subsequent suppuration, the fever, and the individual peculiarities of the injured person are here the most important factors. Amongst the inflammations of the internal organs the most frequently observed are inflammations of the intestines, the kidneys, the lungs, the pleuræ, and the meninges; they are rarely caused by the action of the heat during the reception of the burn, but are much more frequently a result of the gradual alteration in the blood that occurs after the burn.

Duodenitis after Burns.—The origin of the *duodenal ulceration* after burns, mentioned on page 487, has not as yet been clearly explained. Catiano believes that the duodenal ulcers and the intestinal catarrh originate from the destruction of the epithelial layer and the action of the intestinal juice upon the exposed parts. The epithelial destruction is said to be produced by formate of ammonium, which is formed by the decomposition of the hydrocyanic acid in the organism. Hunter also is of the opinion, reasoning from his experiments upon dogs with toluylendiamin, that analogously to the way this substance acts, certain similar products of decomposition in the tissues are produced in cases of burns which are excreted in the bile and are capable of exciting inflammation and ulceration in the duodenal mucous membrane.

Since the time that we have been able, with the help of the modern

method of treating wounds, to control suppuration and its accompanying fever and prostration, as well as the accidental-wound diseases, cases of death from suppuration and other wound infections after burns have become less common.

Prognosis of Burns.—The prognosis of burns may be inferred from what has been said. The more extensive a burn is, so much the more unfavourable is the prognosis, *quoad vitam*. In addition, the location and depth of the burn, as well as the age and constitution of the patient, play an important part. *Quoad functionem*, burns of the third degree, involving the entire thickness of the cutis, are alone to be feared, on account of the cicatricial contractures which may result. Contractures of the joints, abnormal adhesions, such as adhesion of the chin to the neck, adhesions between the two jaws, contractures of the eyelids, etc., result in this way.

Treatment of Burns.—Leaving for the present the treatment of extensive burns endangering life out of consideration, the *local* treatment of burns of the first degree is mainly directed towards the alleviation of the pain. This is best accomplished by the local use of cold in the form of ice bags and ice compresses; by the use of liquor plumbi subacetatis dilutus with ice; by cold baths; by painting with flexible collodium, unguentum cerussæ or unguentum lithargyri Hebræ (unguentum diachylon) after dusting on starch, or starch with oxide of zinc, dermatol, etc., with or without an occlusive dressing of cotton wool. Protective dressings, according to my own experience, are the best for alleviating the pain. By placing the parts in a proper position—if an extremity, by elevating it—the analgesic effects of the above remedies are materially promoted. In some instances it is proper to give subcutaneous injections of morphine. In burns of the *second degree*, when blebs are present, it is advantageous to evacuate the blebs through punctures, but not to remove the elevated epidermis, to cleanse the burned area in the usual way with antiseptic solutions (1 to 1,000 bichloride, or three-per-cent. carbolic-acid solutions), and then to apply an antiseptic powder dressing—for example, zinc oxide, bismuth, iodoform, boric acid, etc. As materials for dressings it is a good plan to use iodoform gauze or sterilised mull covered with cotton, or some other aseptic material, which allows drying to take place. These antiseptic or aseptic dry powder dressings I consider far better for burns than the other kinds of dressings with salves (unguentum simpl., cerussæ, diachylon, vaseline, etc.), or washes (lime-water and linseed oil, equal parts), or solutions of nitrate of silver (arg. nitr., 1 to 100 of water). The dressing dries into a firm aseptic scab, which can be left uncovered by bandages until it falls off of its own accord from the healed wound. In mild burns the

formation of simple aseptic scabs, by means of iodoform, dermatol, bismuth, or zinc oxide, without any other dressing, is a very excellent treatment. After carefnl disinfection of the burn, Nitzsche recommends covering it with linseed oil varnish (1 part oxide of lead dissolved in 25 parts of boiled linseed oil, to which is then added five to ten per cent. of salicylic acid while the oil is hot); over this a layer of cotton is placed, and pressed down as firmly as possible by an elastic bandage. Healing generally follows under a single dressing. The *antiseptic powder dressings* are particnlarly good for burns of the *third degree.* In this way the decomposition of the burned tissues is most easily prevented, and the secretion or suppuration is kept as small as possible. The treatment of burns, like any other wound, should always be conducted with the strictest attention to antiseptic rules, and the less often the dressings are changed the better. A. Bidder recommends painting the burned area with thiolum liquidum or powdering it with thiolum siccum, one of the remedies belonging to the unsaturated sulphur compounds of the hydrocarbons. In *extensive burns* the patient should be placed, when feasible, in a *permanent warm bath* (see page 179). The covering of large granulating surfaces with skin can be hastened by the transplantation of Thiersch skin grafts (§ 42), or by the transplantation of large, fresh skin flaps with pedicles (§ 41). This is the best way of preventing the development of cicatricial contractures or abnormal adhesions. If cicatricial contractures or disfiguring strips of scar tissue have developed after a burn, the cicatrix should be excised and the defect closed by skin flaps with pedicles or Thiersch skin grafts. In the milder cases of contractures following burns, systematic movements and massage are sufficient. The indications for the amputation of extremities which have been extensively burned are, in general, the same as for crushings and severe contusions of an extremity. The amputation should be performed as early as possible after the first symptoms of shock have subsided.

In very extensive burns involving a large portion of the body, the treatment of the general condition of the patient is the first thing to be considered. For the collapse which occurs in conjunction with the burn, the patient should be placed on his back, wrapped up as warmly as possible, and stimulants (wine, whiskey, grog, black coffee, or any warm stimulating drink) should be administered. The subcutaneous injection of ether or camphor is also advantageous, as is the temporary envelopment of the extremities in elastic bandages to drive more blood to the heart (autotransfusion). Restless patients should be given morphine subcutaneously. Blood-letting, which used to be frequently practised, or blood transfusion, should be condemned. On the other hand,

subcutaneous salt infusion (see pages 483, 484) in proper cases of anæmia or of collapse are worth recommending.

Burns from Lightning.—According to Sonnenburg, lightning produces the effect of an electrical shock and has a tearing and burning action. Sometimes the one and sometimes the other of these effects is the more prominent. If people and animals are directly struck by lightning, death occurs immediately in many cases, probably as a result of the violent electrical shock to the nerve centres, especially those governing respiration and circulation. The condition of a person struck by lightning is often precisely similar to one who has suffered a *commotio cerebri.* Paralyses, dysphagia, disturbances of sight, and other nervous phenomena, are also observed. Lightning paralysis has, in general, a favourable prognosis. When considering the paralyses due to strokes of lightning, the true or direct strokes, according to Limbeck, must be carefully distinguished from those occurring indirectly from hæmorrhage—in the brain, for instance. In the true lightning paralysis two stages are to be recognised: In the first, we have to deal with a direct injury to the nerves and muscles caused by the lightning, while in the second we have the picture of a traumatic neurosis (see page 280). Occasionally large vessels are ruptured, followed by death, and now and then extremities are completely severed from the body. The effects of lightning upon the skin are manifested by all sorts of changes, varying from a simple drying of the epidermis to the severest burns. The so-called lightning-marks upon the skin are well known. They consist of branching, brownish-red, zigzag lines, the formation of which is probably connected with the action of the lightning upon the blood. The colouring matter is set free from the red blood-corpuscles by the electrical action of the lightning, and in transuding through the walls of the capillaries or vessels forms marks which correspond to the distribution of the affected vessels (Rollet).

Occurrence of Lightning Strokes in Man.—Sonnenburg states that in Prussia, from 1854 to 1857, according to the official statistics, five hundred and eleven individuals were struck by lightning, and 72·25 per cent. of the cases were fatal. The great majority of the individuals affected were struck while at work in the fields. The statistics of Boudin show that in France from 1835 to 1864, 2,324 people were struck by lightning. During the American civil war, in the summer of 1864, the lightning struck amongst the Eighteenth Missouri Regiment, which was encamped on a hill, and knocked down the entire troop. Almost all the horses and eighteen men were killed, and all the rest were more or less injured. When a row of men or animals is struck by lightning the first and last in the row appear to be the most endangered. It is noticeable, as Sonnenburg has correctly remarked, that bodies of troops on the march have only seldom been struck by lightning.

Treatment.—The treatment of lightning strokes, particularly of the constitutional symptoms, is purely symptomatic. The treatment of the burns is just the same as described above. If any paralyses are left they usually disappear entirely under electrical treatment.

Sun-burn Erythema and Eczema Solare.—In consequence of the action of the sun's rays upon the uncovered skin superficial burns are produced. These occur in summer time, especially in tourists and mountaineers. The skin becomes red and swollen, feels hot, and is more or less painful (*erythema solare*). After a few days the burned layer of epidermis comes off in shreds from the underlying parts. Other cases present a more eczematous appearance, with the formation of blebs (*eczema solare*). For prophylaxis against sun-burns, sun-shades should be carried or veils worn, etc. People with irritable skins when going on mountain tours should cover the exposed parts of their bodies with vaseline, or ungt. litharg. Hebræ, or with starch powder. The burns themselves, as long as severe pain exists, should be treated with applications of liq. plumbi subacetatis dil. and ice, or with ungt. litharg. Hebræ or vaseline, and then powdered with zinc oxide and starch (1 to 5 to 10).

Sun-stroke or Heat-Stroke.—We have yet to consider the so-called sun-stroke or heat-stroke (*insolation*). This is essentially an overheating of the body, and often terminates very quickly in death, particularly in hot climates; but the affection is frequently seen in summer, even in our latitudes, particularly amongst young soldiers who have to take long marches in very hot weather. From the experiments of Krishaber, Schleich, and others, we know that the temperature of a man's body, by immersion of the latter in a hot medium, can be made to rise very rapidly, reaching, for example, 40° to 41° C. (104° to 105·8° F.) in thirty to sixty minutes. Individuals thus treated become restless, the respiration gets very frequent, the pulse rises to 160 or 180, the production of urea is increased, etc. The marked rise in temperature observed in individuals who have been sun-struck coincides with these experiments. In a case which terminated fatally, Bäumler found the temperature of the patient to be 42·9° C. (109·4° F.) one hour after his reception into the hospital.

The symptoms exhibited in sun-stroke or heat-stroke are very characteristic. The face is red, the respiration rapid and sighing, the heart's action is very rapid, and the pupils are dilated. The patient is unconscious, delirious, and convulsions often occur. Death takes place in collapse, sometimes very suddenly. In other cases the course is not so acute; symptoms of collapse are then especially prominent, from which the patient may recover entirely. The decreased secretion of sweat which is noticeable in insolation is important, especially as regards the treatment. At first the secretion of sweat is very much

increased in individuals who work or march in very hot weather, or with the sun beating directly upon the head; but later it is diminished, probably as a result of the diminution of the amount of water in the blood, and then the above-described symptoms of sun-stroke make their appearance. As a result of the diminution in the production of sweat, the loss of heat by evaporation becomes so much diminished that the heat balance is disturbed, and, in consequence of the increased retention of heat, the temperature of the body rises more or less rapidly above the normal, even to a fatal height (Cohnheim). The albuminuria as well as the hæmoglobinuria sometimes coming on in horses, for example, after severe sweating, are ascribed by Maas to the changes in the blood, especially in the serum albumen and the red blood-corpuscles, due to the great loss of water.

The cause of death in sun-stroke or heat-stroke is partly the overheating of the body and partly the great loss of water from the body, or the alteration in the composition of the blood.

Occurrence of Sun-stroke.—Meyer has recently reported a great number of sun-strokes affecting harvest labourers almost like an epidemic in the summers of 1873 and 1880. He ascribes death to *cardiac paralysis*, due to the increased temperature of the body and to an alteration in the blood which he considers uræmic. He distinguishes three stages of the disease—a prodromal stage, a stage of excitement, and a stage of depression. Amongst the numerous cases, only one terminated fatally from meningitis and bilateral pneumonia. American physicians have also described regular epidemics of sun-stroke. In many campaigns sun-strokes have formed a considerable part of the diseases and deaths. As Sonnenburg mentions, the Crusaders appear to have suffered especially large losses by sun-stroke and heat-stroke. On the march through Bithynia and Phrygia, in July, 1099, five hundred men often perished on a single day from sun-stroke. During the American war of secession (1861–'64) there were seventy-two hundred sun-strokes, with three hundred and nineteen deaths. As a result of a forced march during very hot weather in 1848, Sonnenburg states that in the Nineteenth Infantry Regiment of the German army twenty-nine men died. It is a particularly fatal mistake to keep soldiers, while manœuvring or on the march, from drinking.

Treatment of Sun-stroke.—It is my belief that the treatment of sun-stroke or heat-stroke is dependent upon the last-mentioned facts. For prophylactic reasons, it should be stated that the withholding of drink increases the danger of insolation. Hence a regular supply of water to individuals while at work or on the march is to be regarded, to a certain extent, as a protection against sun-stroke. When the dreaded accident of sun-stroke has occurred, our efforts should be directed towards lowering the temperature of the body, stimulating the

secretion of sweat, and combating the weakness of the heart. We try to meet these indications by cold applications and cold baths; by introducing large quantities of water into the stomach and intestinal canal; by the administration internally of stimulants, particularly alcohol; by subcutaneous injection of ether and camphor, and by keeping the patient as quiet as possible. Many authorities have opposed the energetic use of cold applications, cool baths, etc., and advocate warm baths and warm rubbing. I believe that in sun strokes as vigorous an attempt as possible should be made to lower the temperature of the body by cold applications, and, when feasible, by cool baths. Venesection should not be employed; it is useless, and, in fact, usually causes marked collapse.

§ 91. **Effects of Cold (Freezing).**—There are usually distinguished, as in burns, three different degrees in the effects of cold upon the skin. The first degree is characterised by a superficial, erythematous inflammation, the second by the formation of blebs, and the third by eschar formation. The peripheral portions of the body—the toes and fingers, the feet and hands, the nose and ears—are especially exposed to the danger of freezing.

Symptoms of Freezing.—In cases of freezing there usually occurs, in the first place, a contraction of the cutaneous vessels, in consequence of which the affected skin area appears pale, and in many individuals corpse-like, particularly when the fingers are involved; this is often a result of the action of a very slight amount of cold. After the first contraction of the vessels there follows a dilatation throughout the affected area; the latter takes on a deep red colour, and a more or less pronounced swelling develops, which causes an itching or burning sensation. Severe pains may also occur, especially when the frozen parts are rapidly warmed. In the *first degree* of freezing this inflammatory redness and swelling disappear permanently within a few days. But not infrequently the frozen area of skin has a tendency to become affected by a constantly recurring redness, particularly the skin of the nose, ears, toes, and fingers. It may even happen that such cutaneous areas, especially the point of the nose, may, in consequence of a sort of vascular paralysis, remain red throughout life. The so-called chilblains (*perniones*) come from a repeated slight freezing of the fingers and toes. The extensor surfaces especially become the seat, in such cases, of a dark or bluish-red swelling, which has a tendency to ulcerate, and the patient is annoyed by severe itching and burning, particularly in bed, during the change from cold to thawing weather, and in summer. Individuals who have to change constantly from cold to hot atmospheres are very apt to suffer from chilblains. Women, and, as

a general thing, anæmic people, appear to be most susceptible to these mild degrees of freezing.

In a frost-bite of the *second degree* the affected area of skin assumes a deep red or bluish colour and is covered with blebs. In such cases it is a matter of great uncertainty as to whether there will finally occur a complete *restitutio ad integrum*, or whether we do not have to deal with a frost-bite of the *third degree*, with its termination in eschar formation or in gangrene. Speaking generally, the prognosis of the second degree of frost-bite is much more unfavourable than is the case with burns. Whenever blebs develop after a frost-bite there will follow in the majority of cases a gangrene of greater or less depth. It is very suspicious, in such cases, when the absence of sensibility persists for several days, and when the area of skin—apart from the blebs—appears to be almost normal. In the pronounced cases of freezing of the *third degree terminating in mortification* of the affected tissues, the parts involved are usually entirely devoid of sensation, of a dark blue colour, and covered with blebs and scabs; there is no circulation, as the prick of a needle draws no blood. I saw a case of freezing like this, involving both feet and legs, in a deserter who had wandered many days in the forest during extreme cold with insufficient clothing; both legs were amputated and the patient recovered. When extremities are entirely frozen like this, parts of the toes can be broken off through the joints like glass.

Effect of Cold upon the Body.—The constitutional effects of cold upon the human organism is a matter of great interest. If an individual is placed in a cold medium, he will lose heat the more rapidly the lower the temperature of the medium and the quieter he remains. As long as a person is in a position to perform active movements he can successfully withstand severe degrees of cold, such as — 42° to — 45° C. (– 43° to — 49° F.). When the muscles become quiet the danger of freezing is particularly great.

Experiments in the Reduction of the Temperature of Animals.—Walther, Howarth, and Cohnheim, experimenting with animals, have studied the consequences of cooling off the organism. If a rabbit or a small dog is immersed to the neck in water at a temperature of about 0° C., or placed in a small vessel surrounded by a cooling mixture, in which movement is impossible, the temperature gradually sinks. If the animal is kept in the cold medium until the rectal temperature becomes 18° to 20° C. (68° F.), as a result of this cooling off a general paralytic condition becomes evident. The animal is no longer able to stand on its legs, and lies as though dead, the contractions of the heart are weak and slow (16 to 20 beats in the minute), the frequency of respiration is also diminished, peristalsis of the intestine ceases, and the urinary bladder, though filled to distention, is not emptied. The eyes

are widely opened, the cornea shows almost no reaction, and the pupils are very widely dilated and almost entirely insensitive to light. If, after the animal has been cooled down to a temperature of 18° C. (64·4° F.), he is allowed to remain in the cold medium still longer, death usually soon occurs in the majority of cases from cardiac paralysis. Animals whose temperature has been reduced to 18° C. ordinarily die when allowed to lie quietly at room temperatures; but their temperature will again rise to the normal if they are placed in a hot medium—for example, in a vessel at a temperature of 40° C. (104° F.). At first the temperature rises very slowly to about 30° C. (86° F.), and then more rapidly; within about two to three hours the temperature of the animal rises from 18° to 39° C. (64·4° to 102° F.). The chilled animal can also be made to become warm again by artificial respiration. As the temperature of the body rises the general paralytic condition disappears, the activity of the heart and lungs increases, intestinal peristalsis reappears, the urinary bladder is emptied, and finally the brain regains its function and the animal is again full of life. But many of these animals die later on after they have recovered their normal temperature, and occasionally such animals are even subject to elevations of temperature with subsequent pronounced emaciation.

According to Catiano, death from freezing is due essentially to cerebral anæmia with secondary paralysis of the respiratory nerves.

It is not known at what temperature man ceases to live. Temperatures of 24° to 26° C. (75·2° to 78·8° F.) in the rectum have been repeatedly recorded during the winter time in drunken people who afterwards—generally within a few hours—completely recovered. Cohnheim believes that a complete and rapid recovery is doubtful when the temperature in man goes down to 20° to 18° C. (68° to 64·2° F.). The symptoms manifested by man correspond entirely with those obtained by animal experimentation. When a person becomes very cold there is a pronounced apathy and sleepiness, the pulse and respiration are slow, and the pupils are widely dilated and react sluggishly. Death from freezing is favoured by diminished muscular movement. According to Sonnenburg, thirty-six per cent. of those who are frozen are drunk at the time.

Treatment of Freezing.—In treating the mildest grade of frost-bite the affected part should not be warmed too rapidly, but should be rubbed with snow or ice water and then wrapped in wet cloths. A great number of remedies have been suggested for chilblains. It is always important to attend to the general condition of individuals with a tendency to chilblains, and, as a prophylactic measure, to recommend warm coverings for the hands and feet when the cold period of the year comes on. When chilblains are present we try rubbing the parts with snow and ice water, ice poultices, a foot bath of ice water followed by the application of wet cloths, painting the parts with collodion, traumaticin, glue, enveloping them with strips of adhesive

plaster, the application of tinct. iodi. followed by a warm, moist poultice, mild caustics, such as dilute hydrochloric acid (1 to 25 or 30 of water), tinct. cantharid., etc. Various kinds of salves have been recommended. Excoriated, ulcerated frost-bites are best treated with iodoform or zinc oxide and starch, or with ungt. litharg. Hebræ (ungt. diachylon), with or without starch, and oxide of zinc. For red noses following frost-bite I should recommend punctures made not too deep with the needle point of the Paquelin cautery, or the galvano-cautery, which causes the redness to disappear without giving rise to a visible scar.

In cases of extensive and deep freezing of the second and third degree involving an extremity, vertical suspension of the limb should be immediately employed to facilitate the restoration of the circulation in the frozen parts. Wet applications may be combined with the elevated position to stimulate the local vasomotor ganglia. If there is necrosis of the tissues, antiseptic dressings with iodoform, or with iodoform and charcoal, naphthaline, etc., or antiseptic continuous irrigation, should be used as for burns. If the frozen surface is very large the permanent water bath should be employed (see page 180). If gangrene of an extremity develops, amputation or disarticulation should not be undertaken prematurely, but antiseptic treatment should be kept up until the line of demarcation has become distinct. Spreading inflammation and suppuration are to be combated by multiple incisions, etc.

The treatment of freezing of the entire body is as follows: In the first place, the person who has been frozen must not be warmed too suddenly. He should be carried into an unheated room, rubbed with cold wet cloths, and then placed in a bath at a temperature of 16° to 18° C. (60·8° to 64·4° F.), which is gradually—within two to three hours—brought up to 30° C. (86° F.). It is often necessary and always very useful to perform artificial respiration. Ether and camphor are given subcutaneously, and, as soon as the patient can swallow, alcoholic stimulants are freely administered. Wrapping the extremities in cold wet cloths is excellent for the severe pains in the limbs which occur as the patient returns to life. Bergmann and Reyher recommend suspension of the frozen extremities at the earliest possible moment, to limit the gangrene. There should be no hesitation in applying vertical extension to all four extremities.

§ 92. **Subcutaneous Injuries of Soft Parts.**—The most common and important subcutaneous injury which the soft parts suffer is contusion. It usually results from a bruising or crushing produced by some blunt object, by a thrust, blow, or fall. The soft parts are either squeezed

together as a whole, or pressed against a neighbouring bone. The degree of the crush, of course, varies all the way from a slight bloody discolouration, a bloody suffusion or suggillation, to a crushing of the bones and soft parts into a pulpy mass. In many individuals, such as the so-called bleeders (see page 57), a comparatively large effusion of blood not infrequently follows a trifling contusion of the tissues. Furthermore, spontaneous subcutaneous hæmorrhages are not uncommon in bleeders.

The different soft tissues of the body possess a very unequal power of resisting a contusing force. As Gussenbauer's experiments teach, and as daily experience proves, the loose connective tissue and the small vessels and capillaries it contains have the least powers of resistance. The skin, the fascia, the tendons and larger vessels exhibit a remarkable resistance to the effects of a contusing force. In general, two degrees of contusion can be distinguished, the first being the contusion with preservation of the affected parts, and the second with their destruction (mortification, necrosis).

Symptoms of Contusion.—The most important of the symptoms of a contusion of the subcutaneous tissues is *hæmorrhage.* In the majority of cases the extravasated blood comes from the capillaries and veins, the arteries possessing great powers of resistance to violence inflicted by a blunt object. As a result of the laceration of the lymph vessels, there is also an extravasation of lymph, and it sometimes happens that the extravasation is made up mostly of lymph. This lymph extravasate may form a fluctuating tumour, and usually is made up of a citron-yellow or a slightly reddish-coloured fluid having the composition of lymph or blood serum. According to Gussenbauer, these lymph effusions are particularly apt to occur when the skin is more or less displaced by a traumatism from its position in relation to the underlying parts. This displacement causes a laceration of the lymphatic vessels which permeate the subcutaneous cellular tissue. The lymph effusions are consequently usually located in the subcutaneous cellular tissue. As a general thing, the hæmorrhage in subcutaneous injuries, even when large vessels are ruptured, is not dangerous, and, for the most part, soon stops in consequence of the rapid coagulation which usually follows contusions. The extravasated blood is either evenly distributed throughout the contused tissues as a hæmorrhagic infiltration, or it forms small, circumscribed collections which are called ecchymoses or suggillations. The larger collections of blood are called hæmatomata; suffusions, on the other hand, designate more superficial, large, spread-out collections of blood. The extravasated blood distributes itself through the tissues in the direction of least

resistance, especially between the fasciculi of connective tissue, between the muscles, in the subcutaneous cellular tissue, etc. If the bleeding takes place into a free cavity, a bursa or a joint, or into one of the cavities of the body, a large collection of blood may result. The collections of blood in the cavities of the body have their special nomenclature, an effusion of blood into a joint being called hæmarthros; into the pleura, hæmothorax or hæmatothorax, etc. Other blood effusions have likewise received particular names, according to the locality in which they occur—for example, the blood tumour on the head of a newborn infant is called a cephalo-hæmatoma; a hæmorrhage into the brain, an apoplexy, etc.

The hæmorrhages into the large cavities of the body are, of course, dangerous, and are not infrequently fatal, partly because of the amount of blood poured out, which has been able to escape freely, and partly because of the pressure of the extravasation upon organs such as the heart or brain, which are necessary for the preservation of life. It is well known that no less danger attaches to hæmorrhages into the brain itself, the so-called apoplexies by which, apart from other disturbances, the substance of the brain is partially destroyed, and rapidly developing paralyses and death are produced.

As the larger arteries are in general deeply located in the soft parts, and their tough, elastic walls are not easily torn, it but rarely happens that they suffer a subcutaneous rupture. But if it does happen as a result of unusual violence, a pulsating tumour may be formed—a so-called traumatic aneurysm (§ 95, Aneurysm). When the extravasated blood comes from an artery or from the larger veins the hydrostatic pressure in the connective-tissue spaces usually soon rises to such an extent as to arrest the bleeding, the rupture in the artery being closed by a coagulum. But the presence of pulsation in an extravasation of blood does not in all cases indicate a subcutaneous injury to an artery. The pulsation may be only apparent, and due to the rise and fall of the more or less tense extravasation caused by the pulsation of the underlying uninjured artery. If the apparent pulsation of a tumour is communicated from an adjoining artery, the tumour shows no increase in all dimensions with each systole, but only in a direction at right angles to the underlying artery. On the other hand, an artery may have received an injury, and yet, on account of the thickness of the overlying layers of tissue, it will be impossible to detect pulsation.

The recognition of extravasated blood when the hæmorrhage is superficial presents no difficulties. The hæmorrhages into the skin and subcutaneous cellular tissue are usually seen immediately. In such cases the skin has a dark-red or violet colour and the greater the

hæmorrhage the more extensive is the doughy and fluctuating tumour. As a result of the distribution of the colouring matter of the blood in the tissues of the cutis, there occur within the first few days following the injury various shades of discolouration, of which green, dark green and yellow usually predominate; they often persist a week or so as a symptom of the contusion which the skin has suffered. The larger the swelling the greater is the subcutaneous extravasation of blood. The more deeply situated extravasations in the extremities cannot be recognised solely by inspection; it is usually necessary to make use of palpation of the contused soft parts. As a general thing, crushed soft parts are rendered hard by the bloody infiltration; they are thickened and give a feeling of resistance. In the worst degree of contusions, on the other hand, such as those in which the soft parts and the bones are crushed to a pulp by the wheel of a heavy waggon, the affected parts are changed into a shapeless mass devoid of circulation, with or without preservation of the cutaneous coverings.

The comparatively rare extravasations of pure lymph are distinguished from blood extravasations by their slower increase in volume, by the absence of discolouration of the skin, and of all the other symptoms which occur as a result of the coagulation of blood and of the presence of the colouring matter of blood in the tissues.

Fever in Subcutaneous Injuries.—Following subcutaneous injuries of tissue there will sometimes be fever, and yet there will be no symptoms worth speaking of which indicate either inflammation or suppuration; thus in subcutaneous extravasations of blood or subcutaneous fractures there will sometimes be an elevation of temperature to 101° to 102° F., or even as high as 104° F. The cause of this fever is to be ascribed, in these cases, to the taking up of the products of destruction in the tissues by the circulating fluids of the body (see § 62, Fever).

In addition to the elements of the blood and lymph, ingredients of the contused tissues are also taken up into the circulation, especially fat, which may enter the blood and lymph vessels, thus causing extensive fat emboli in the lungs and brain. Fat emboli are particularly apt to occur when the marrow of a bone is injured, as in a fracture. When we come to the latter subject these emboli will be discussed more fully.

Disturbance of Function.—The disturbance of function exhibited by the contused soft parts varies greatly according to the portion of the body affected and the degree of the contusion. A contused joint in which there is a large intra-articular extravasation of blood naturally has its mobility affected. A crushed muscle which has suffered complete rupture will be unable to contract, and the rupture of a nerve,

such as a mixed nerve in an extremity, will give rise to a paralysis of the muscles which it supplies.

The pain which is felt in a contusion at the moment the violence is exhibited varies greatly, according to the richness of the nerve supply in the affected portion of the body, and according to the amount of crushing sustained by the nerves. If from the effects of the violence a large sensory nerve is injured, the pain at the moment the injury is received is very severe, and the person who has been injured feels the pain of the contusion not only at the point where the injury was received, but usually all along the course of the nerve, and so at points widely removed from the injury.

Results of the Contusion of a Nerve.—Concussion of the nerve substance is particularly apt to occur in contusions of the skull. When a blow is received on the head, the symptoms of concussion of the brain (*commotio cerebri*) are very plain, and eventually may be combined with so-called focal symptoms indicating an injury to some particular part of the brain, or with symptoms of compression from extravasated blood which may collect between the brain and the skull (see Special Surgery). In other cases the symptoms of concussion of the brain and spinal cord are produced indirectly, as by falls upon the feet. In the same way a concussion of the nervous system or a contusion of a nerve due to an injury to any part of the body can reflexly affect the central nervous system to such a degree as to give rise to the set of symptoms known as shock (see § 63).

The severity of the injury to the skin is of the greatest importance as regards the subsequent course of the contusion, but the extent of this injury cannot always be determined from the first. The severity of the injury to the skin depends upon the shape of the body inflicting the contusion and the force with which it acts, and upon the elasticity and thickness of the skin, which vary in different portions of the body and in different individuals.

If the skin is contused to such an extent that all the vessels are ruptured and the circulation in the affected area is stopped, the natural consequence is death or necrosis of the tissues thus deprived of nutrition. An area of skin like this contains no blood, and none flows when an incision is made into it, and no pain from the incision will be felt by the patient. Sometimes an apparently dead portion of skin recovers, the circulation becomes established here and there, and then the entire thickness or the entire area of contused skin, does not perish. The subcutaneous soft parts and the bones, like the skin, may also suffer a primary necrosis in consequence of a crushing injury. There is another kind of death of tissue which is *secondary* in its

nature and caused by the inflammation that takes place after the injury.

If the integrity of the skin has been preserved, absorption of the subcutaneous extravasation of blood usually takes place without any particular disturbance. During the first few days following the injury the contused skin exhibits the characteristic changes which take place in the colouring matter of the blood. The discolouration, which at the outset is dark blue or bluish red, becomes brownish, dark green, green, and finally yellow ; the yellow stain often persists for weeks or months. Occasionally the areas of discoloured skin are very extensive.

Fig. 310.—Collection of blood in a retro-peritoneal lymph gland resulting from a subcutaneous laceration and contusion of the psoas muscle with fracture of the pelvis. × 30.

Absorption of the Blood Extravasation.—The extravasated blood is absorbed as follows: First the fluid portion of the coagulum is taken up and carried off by the lymphatic vessels, and then the fibrinous portion becomes liquefied and is likewise absorbed by the lymphatics. Some of the colourless blood-corpuscles disintegrate when coagulation takes place, while others are forced out of the clot as it coagulates, or leave it, according to Cohnheim, by spontaneous locomotion. The chief interest in the resorption of extravasated blood centres upon the fate of the red blood-corpuscles. Many of them get into the lymph channels and are carried by the lymph current to the nearest lymphatic glands, where they occasionally accumulate in such numbers as to cause marked swelling of the glands and to make a section of their parenchyma present an evenly distributed dark-red appearance. I found in a case of a fractured pelvis, with a subcutaneous rupture and contusion of the psoas muscle, a very extensive collection of red blood-cells in the retroperitoneal lymph glands. Similar accumulations of red blood-corpuscles or of blood pigment (Fig. 311) were also present in other organs, particularly the liver. These observations show that red blood-corpuscles are taken up in great numbers by the lymph channels and enter the circulation. Another portion of the red corpuscles disappear *in loco* by granular degeneration after they

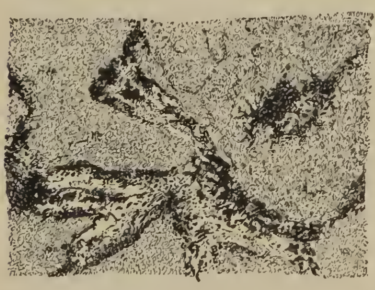


Fig. 311.—Collection of blood in the liver after subcutaneous laceration and contusion of the psoas muscle with fracture of the pelvis. × 80.

have previously become decolourised by loss of their colouring matter. The colouring matter of the blood is diffused through the surrounding parts and a portion of it is simply absorbed, while another portion is changed into crystalline hæmatoidin—i. e., into oblique rhomboid crystals about 0·1 millimetre long, of a yellowish-red to brick-red colour. Together with these crystalline forms there also occur orange-yellow needles and small angular or indentated rust-coloured particles. The hæmatoidin is not formed solely by direct transformation of free red blood-corpuscles, but also originates intracellularly—that is, the red corpuscles are taken up by the lymph corpuscles and the colourless blood-corpuscles and are here changed into pigment (Langhans).

Other Terminations of Extravasations of Blood.—The most satisfactory termination for an extravasation of blood is its complete absorption in the manner described above. When the extravasation is diffuse, absorption is the commonest termination. The particles of pigment and crystals of hæmatoidin gradually disappear in the course of months, leaving nothing which recalls the hæmorrhage that has occurred or the injury which the tissues have suffered. In severer contusions with larger, more circumscribed extravasations of blood, the extravasation is gradually displaced by new-formed connective tissue, as in the so-called organisation of a thrombus in a vessel (see page 294).

Organisation of the Extravasated Blood.—In contusions of periosteum, or of bone or its marrow, the product of the organisation is not connective tissue but bone.

Sometimes the organisation of the extravasated blood into connective tissue is confined to the outer layers of the extravasation, as, for example, in cerebral hæmorrhages or in hæmorrhages into the substance of the thyroid gland or of a tumour. In this way there develops at the point where the extravasation occurred a *cyst*—that is, a space filled usually with a yellowish-red fluid and enclosed by a connective-tissue capsule. After the liquid in the cyst has been absorbed a true connective-tissue cicatrix may eventually develop.

Drying, Calcification, Suppuration, and Gangrene of the Extravasated Blood.—In rare cases the extravasated blood becomes dried, or calcareous concretions are formed by deposition of lime salts. The unfavourable changes which the extravasation may undergo are suppuration, and particularly putrefactive decomposition and gangrene. These terminations are only brought about, as mentioned in § 57, by bacterial infection through a cutaneous injury, or, in rare instances, through the circulation, and are seldom observed in subcutaneous extravasations of blood. When infection does occur it is usually due to a superficial cutaneous injury or to necrosis of the skin caused by the injury. It is also to be borne in mind that bacteria may be forced into the skin

when the latter is subjected to violence, and they will then find a favourable medium for their development in the extravasated blood and the contused skin.

Absorption of Extravasated Lymph.—The more or less pure lymph extravasations are ordinarily absorbed very slowly, and they sometimes persist for months as a soft fluctuating tumour; it is an exceedingly rare occurrence for them to undergo suppuration or putrefactive change. The repair of a wound and the regeneration of injured tissues are described in § 61.

Treatment of Contusions.—The treatment of a contusion is, in the first place, directed towards as rapid an absorption as possible of the extravasation. A great number of the slighter contusions get well without assistance in a comparatively short time. If a contusion of soft parts—on an extremity, for instance—comes under observation immediately after it has been received, and if a fracture has been positively excluded, the injured extremity should be placed in an elevated position to diminish the pain and check the subcutaneous hæmorrhage. With the same object in view ice is employed locally, or cold applications, to which may also be added substances like acetate of lead, chloride of ammonium, spirits of camphor, etc. It is always advantageous for arresting subcutaneous hæmorrhage to apply a dressing which exerts a slight pressure. If the skin is intact and there is a considerable extravasation of blood, the latter should be mechanically forced into the interstices of the tissues and into the lymph channels by being gently kneaded and rubbed in a centripetal direction by the thumbs, fingers, or palms. In this manner the absorption of the extravasation is hastened. After the massage, it is often advantageous to wrap the injured portion of the extremity in a flannel, mull, or cotton bandage to prevent a recurrence of the subcutaneous hæmorrhage and swelling. As a general thing, it is a good plan, immediately after the massage, to make the patient move his contused muscles or joint. This increases the effect of the massage and materially hastens the absorption of the extravasation. Massage is suitable for subcutaneous ruptures and contusions like sprains of joints, which can often be cured by this method within a few days; in fact, the effects of massage upon a sprain often seem perfectly wonderful to the laity. The patient may have suffered the severest kind of pain when making the least attempt to stand upon his contused foot or ankle, and yet after massage has been practised but once he will be able to get about with very slight pain, or practically none at all.

The massage must be repeated daily, and in the most favourable cases three to five sittings will be enough to effect a cure, while in

others the massage must be continued for a longer time. The sooner the massage can be undertaken after the injury the more rapid will be the success.

Technique of Massage.—The technique of massage is not as simple as it appears. It has recently been employed with success for all sorts of troubles. Before beginning the treatment upon the injured portion of the body, it is very often advisable to start with an introductory massage of the healthy parts on the proximal side of the injury, using centripetally directed strokes of the hand to empty the veins and lymphatic vessels and thus promote the absorption from the injured portion of the body. Massage of the healthy parts on the proximal side of the injury should be employed in all cases where massage of the actually inflamed or injured portion of the body is impossible on account of a cutaneous injury or too great pain. The parts to be massaged and the hands of the *masseur* should first be smeared with lard or vaseline, to facilitate the strokes given by the hand.

There are in general four methods of employing massage: 1. *Effleurage*, or centripetally directed strokes of varying strength made with the palm of the hand or its radial border. 2. *Massage à friction*, or vigorous circular rubs with the hand or finger tips, and particularly with the thumbs, to break up and scatter pathological products. 3. *Pétrissage*, or elevation of a portion of tissue with both hands, or with the fingers of one hand, followed by squeezing and kneading the parts thus lifted. 4. *Tapotement*, or beating and striking the part under treatment with the hand, or with some instrument made of wood, rubber, etc., specially constructed for the purpose. The length of time occupied at each sitting varies greatly; it may be two to three minutes, or as much as five to fifteen minutes or longer, depending upon the extent of surface to be covered.

Of course, a great number of contusions are not suited for massage. In this category belong all cases in which the skin has been severely damaged by mechanical violence, or where large vessels have been ruptured, in consequence of which considerable extravasations of blood have occurred, or where, in addition to an extensive contusion and crushing of soft parts, there is also a fracture of a bone. Every cutaneous abrasion, no matter how superficial it may be, must be carefully treated upon antiseptic principles. The subcutaneous extravasation of blood will also be diminished by an antiseptic dressing which exerts pressure. In other cases there may be a scab of dried blood which will protect the cutaneous injury from infection. If suppuration occurs—i. e., if the skin becomes hot, red, and tender, and fluctuation is detected—incisions should be made in the most dependent parts, drainage inserted, and antiseptic dressings applied. Should putrefaction of the extravasated blood set in—i. e., should there be a rapid increase in the size of the inflammatory tumour, with high fever and chills—vigorous treatment must be adopted. Incisions should be made

as large and numerous as possible in order that the secretion from the wound may freely escape. The wound should then be disinfected with a 1 to 1,000 solution of bichloride of mercury, or with a three- to five-per-cent. solution of carbolic acid, and all gangrenous shreds of tissue removed. Early amputation is sometimes indicated when there are extensive gangrenous changes, but, as a rule, such interference is very rarely called for. When large extravasations of blood are absorbed very slowly, or at best but incompletely, it is allowable to open them up, scrape them out, and drain the cavity thus formed. This applies especially to the above-mentioned purely lymph extravasations. They neither coagulate nor become absorbed, and are rather more apt to increase in size; consequently the majority of these cases should be treated by operation. They should be opened as much as is necessary by an incision and scraped out. Furthermore, when a large vessel is ruptured subcutaneously, unless the hæmorrhage ceases, the vessel must eventually be sought for at the point of the injury and ligated on the proximal and distal side of the injured spot, and the intervening contused portion of the vessel extirpated. The special treatment for contusions of joints and bones is described in the paragraphs upon these subjects.

Muscular paralyses following contusions of nerves, if the continuity of the nerve is not interrupted, usually disappear under electrical treatment. If the nerve has been completely divided, neurorrhaphy should be performed in the ordinary way (see page 469).

Subcutaneous Rupture of Healthy Muscles and Tendons.—The subcutaneous rupture of healthy muscles and tendons ordinarily only occurs as a result of the action of great force, such as a violent muscular effort or an excessive strain at the time of the dislocation of a joint, or from direct violence, such as a blow, etc. As a result of excessive muscular exertion, as in jumping, there may occur a rupture of the gastrocnemius or of the tendo Achillis. In a similar manner there may follow a rupture of the tendon of the quadriceps extensor when an individual is in danger of falling and tries to hold himself on his feet by vigorously contracting the extensor muscles of the leg. The ruptures may be partial or complete, and occur either in the muscle or the tendon. Purely muscular ruptures are most common in long-bellied muscles possessing either a very short tendon or none at all, such as the rectus abdominis or the sterno-cleido-mastoid. Not infrequently tendons are torn from their points of insertion with or without a tearing away of bone substance (so-called torn fractures). The tear takes place where there is the least resistance. If muscles and tendons endure the increased amount of strain, their points of insertion, the bony

prominences, may break off, and thus there may result transverse fractures of the patella, or fractures of the processus calcanei posterior, in consequence of excessive strain from the quadriceps femoris or gastrocnemius with its tendo Achillis.

The tearing away of the muscles or tendons at their points of insertion on the bones, with or without laceration of bone substance, is particularly apt to occur in traumatic dislocations of joints such as the shoulder or hip.

Very rarely ruptures of muscles or tendons are produced by direct violence—a blow or a thrust.

If muscles or tendons have suffered a loss in their powers of resistance as a result of inflammation or degenerative processes, such as fatty or waxy degeneration accompanying constitutional febrile diseases, a very moderate amount of mechanical violence may prove sufficient to cause a rupture. These ruptures of diseased muscles and tendons are called *spontaneous*, in contradistinction to the ruptures of healthy muscles and tendons.

The *symptoms* of subcutaneous rupture of a tendon or muscle—an accident which is most commonly observed in military practice—consist first of all in the inability to perform those movements of which the ruptured muscle is ordinarily capable. At the injured point it is usually evident that the ruptured ends of the muscles or tendons are separated by a greater or less interval, and that in this gap in the tissues there is a correspondingly large fluctuating extravasation of blood. If the latter is considerable, it may render the diagnosis difficult. The patients themselves often direct the attention of the physician to the nature of their injury by positively stating that they have plainly felt or heard a rupture of the tissues.

The subcutaneous muscular and tendinous ruptures usually heal readily under proper treatment, without being followed by any disturbance whatsoever; suppuration is scarcely ever observed. Even when no suitable treatment is adopted, the muscular and tendinous stumps very often heal together by the formation of an interposed connective-tissue cicatrix, such as takes place, for example, after the subcutaneous division of the tendons and muscles undertaken for the cure of club-foot or other joint or muscular contractures. The connective-tissue cicatrix interposed between the muscular and tendinous stumps is at the outset adherent on all sides to the surrounding parts. These adhesions are gradually torn or stretched as soon as the patient again begins to use his muscles.

Even after loss of muscular substance such as follows suppuration, the two stumps of the muscle can become bound together by a con-

nective-tissue cicatrix, a kind of *inscriptio tendinea*, and the muscle be rendered capable of performing its functions.

It sometimes happens after subcutaneous rupture of a tendon that, in consequence of the retraction of the central end of the tendon, the two stumps do not directly unite with one another but with the overlying skin. Both tendon stumps in such cases then become adherent to the skin, and the latter may become so mobile that it follows the movements of the tendon, and the latter performs its normal functions.

After muscular ruptures subsequent contractures sometimes develop. In this class of cases belongs the so-called congenital form of wry-neck (*caput obstipum*), which is due generally to a partial rupture of the sterno-mastoid muscle, usually the result of operative interference during birth. According to Stromeyer and Volkmann, the contracture is produced in part by a cicatricial shrinkage of the muscular substance, and in part by the oblique position of the head instinctively assumed from the time of birth. According to Petersen, the sternomastoid muscle involved in *caput obstipum* is congenitally shortened. In other cases a contracture after muscular and tendinous rupture is caused by the action of the antagonistic groups. But it is certain, as the division of tendons for contractures also proves, that these so-called antagonistic muscular contractures are not by any means so severe nor so common as was formerly believed to be the case. We shall discuss this question more fully under the subject of contractures of the hand and foot.

Treatment of Subcutaneous Muscular and Tendinous Ruptures.—This consists essentially in approximating as closely as possible the divided and separated ends of the muscles and tendons, and preventing the use of the muscles or tendons, whenever possible, by immobilisation of the affected portion of the body. Wherever it is feasible, an attempt should be made, after division of the skin under antiseptic precautions, to obtain primary union by sutures connecting the muscular or tendinous stumps (see Tenorrhaphy).

Occurrence of Subcutaneous Muscular and Tendinous Ruptures.—Recently Maydl, in particular, has written a very exhaustive treatise upon this subject, and, by collecting a great number of cases of rupture of muscles and tendons on the trunk and extremities, he has demonstrated that the injury is not so rare as was formerly believed. He has collected sixty-one cases of rupture of the quadriceps extensor muscle or of its tendon, and fifty-seven cases of rupture of the ligamentum patellæ. He states that one hundred and three cases of rupture of the muscles of the upper extremity and of the muscles and tendons of the trunk, including the muscles attached to the pelvis, have been published ; of these, the most common ruptures were those of the sterno-cleido-mastoid, the rectus abdominis, the biceps brachii, the psoas and biceps femoris muscles.

Muscular Hernia.—The protrusion of a portion of a muscle through an unhealed rupture in its overlying fascia or sheath is called a muscular hernia. In cases of this description, during the contraction of the affected muscle, a portion of its belly pushes itself through the gaping tear in the fascia or sheath of the muscle and forms an elastic fluctuating tumour (Fig. 312). Herniæ of the straight abdominal muscles and of the muscles of the thigh seem to be the most common, occurring particularly in the soldiers of cavalry and artillery regiments. As Baudin has recently demonstrated, the affection is not so rare as was formerly believed. In the thigh the development of muscular herniæ after subcutaneous rupture of the fascia is favoured by the very slight distensibility of the fascia, by its tense arrangement on the inner side of the leg, and by a frequently repeated, excessive stretching of the adductors such as occurs in riding. The observations of Baudin show that a sudden rupture of the fascia does not necessarily occur. Much more commonly there is a gradual forcing asunder and tearing apart of the fibres of the fascia. On account of the poor nerve supply in the fascia, a tear in the latter is not ordinarily accompanied by pain. As regards the diagnosis, it is characteristic for tumours due to muscular herniæ to disappear or become prominent as the points of origin and insertion of the affected muscle are separated from or approximated to one another.

Fig. 312.—Muscular hernia (adductor longus) resulting from a rupture of the fascia, due to a fall from a horse. (Rawitz.)

If the discomfort caused by such a muscular hernia is considerable, an operation should be undertaken for its cure. The skin is incised, the ruptured fascia exposed, and the edges of the rent freshened and drawn together by catgut sutures. After healing is complete, an elastic dressing which exerts pressure in the form of an elastic girdle, possibly with a flat pad, should be worn for some time. In mild cases, and when patients are afraid of the knife, we are forced to confine ourselves to a purely palliative treatment of the affection by an elastic girdle with a flat pad.

Dislocations of Muscles and Tendons.—Displacements of muscles and tendons after laceration of their fasciæ and synovial sheaths have received the name of dislocations. In general they are very rarely observed, and mainly occur when the muscle or tendon in question by some violent movement slips over a bony prominence where it is held

fast. Displacement of the tendons of the peronei muscles on to the outer surface of the external malleolus may occur in severe sprains of the ankle joint. There is a division of opinion as to the frequency with which dislocation of the biceps tendon occurs from the bicipital groove over the lesser tuberosity of the humerus. According to Cowper, the dislocation is particularly apt to occur in forced elevation of the arm, and the accident is characterised by severe pain in the region of the lesser tuberosity, and by inability to move the shoulder joint. Jarjavay, Pitha and others doubt the occurrence of simple dislocations of the biceps tendon unaccompanied by dislocation or fracture of the upper end of the humerus.

The reposition of the dislocated tendons—of the peronei, for example—is an easy matter in recent cases. To keep the tendons in their proper position after they have been replaced, a suitable retentive dressing should be applied so as to exert pressure upon the point where the dislocation has occurred, while the joint is made to assume a suitable position, which in dislocation of the peronei consists in supinating the foot. As dislocations of tendons are particularly apt to occur when the bony grooves are not deep enough, and as this condition also favours their recurrence, it is occasionally advantageous to make use of Albert's method, and deepen the groove subperiosteally with a gouge and then reunite the elevated periosteum by catgut sutures. Maydl also recommends freshening and suturing together the lacerated edges of the tendon sheath. If there is atrophy of the tendon sheath, a portion of the periosteum may be turned over the tendon and sutured to its sheath.

Dislocations of Nerves.—These occur under conditions similar to those described for dislocations of the tendons and muscles. Dislocation of the ulnar nerve from its groove behind the internal condyle of the humerus is a particularly familiar accident. In obstinate cases the bony groove should be deepened subperiosteally with a gouge, or the nerve should be secured in position by suturing its sheath to the fascia or inner border of the triceps tendon and covering in the nerve by suturing the fascia over it to the periosteum (Stabb).

Subcutaneous stretching, tearing, or laceration of the capsules of joints and their ligaments—the so-called sprains—will be discussed under the subject of Injuries of Joints (§ 121).

§ 93. **The Diseases of the Skin and Cellular Tissue.**—The diseases of the skin are very numerous, since it is so much exposed to injurious influences from without, and since it bears such an intimate relationship to the whole organism. This relationship to the rest of the system explains why the skin presents *secondary* symptomatic changes

in diseased conditions of the nervous system, the blood, the lymphatic system, and the internal organs.

The trophoneurotic cutaneous affections are extremely interesting. We know that, as a result of long-continued irritation of peripheral nerves, there may occur not only degenerative changes in the peripheral portions of these nerves, accompanied by trophic disturbances, but that also the peripheral changes may advance in the form of an ascending neuritis to the spinal cord and brain. These secondary diseases of the central nervous system may then in turn give rise to trophic disturbances of the skin, to inflammation, gangrene, ulcers, vasomotor disturbances, etc. I should also mention at this place the reflex angioneuroses, in which, as a result of various kinds of irritation such as may proceed from the sexual organs, manifold polymorphous exanthemata including wheals, papular efflorescences, erythema nodosum, etc., may occur.

We shall confine ourselves here to only the most important diseases of the skin in so far as they come under the treatment of the surgeon.

Acute Inflammations of the Skin.—The principal acute inflammations of the skin of interest to the surgeon are erythema, eczema, furuncle, carbuncle, and erysipelas; the latter is described in § 71.

1. **Erythema.**—By erythema (dermatitis erythematosa) is understood an acute, circumscribed inflammation mainly involving the papillary layer of the skin. In consequence of the inflammatory hyperæmia the skin is reddened and somewhat swollen. The temperature of the affected area is elevated, and there is usually a sharp, burning pain. The anatomical changes in erythema consist in a serous exudation into the space between the most superficial layer of the cutis and the rete Malpighii, and in a more or less pronounced infiltration with leucocytes. The cells of the rete Malpighii are generally somewhat enlarged and swollen. As a result of the exudation, the epidermis is often elevated in the form of small blebs which are filled with serum or pus. Erythema usually terminates in a complete *restitutio ad integrum*, without leaving any visible cicatrix. The epidermis comes off mostly in the form of scales or large flakes. If the irritation continues long enough, small ulcers may occasionally develop from the blebs, but these, too, as a rule, heal very rapidly. The causes of erythema are very varied. Ordinarily the disease originates from a local mechanical, thermal, or chemical irritation; it may thus come from superficial burns or frost-bites, from continued irritation of the skin by wet bichloride or carbolic dressings, or it may be caused by sweat, urine, or pus, particularly in localities where areas of skin rub together, as at the anus, the vulva,

in the axilla, or after the ingestion of various kinds of food or medicaments (quinine), etc.

Erythema Multiforme, Erythema Nodosum.—In endocarditis, as a result of infection by micro-organisms, and in all cases of acute and chronic infectious diseases, various forms of erythema sometimes occur, particularly erythema multiforme and erythema nodosum. The etiology of erythema multiforme is extremely varied. In addition to the toxic influences which bacteria exert, a very important part is played by alterations in the nervous system, including both the peripheral nerves and the central nervous system, and by irritations of the skin when the nervous system is normal.

The Treatment of Erythema consists in the use of washings and baths. For pure hyperæmia ice and lead-water should be employed, and the parts should be covered with unguentum lithargyri Hebræ (unguentum diachylon), or vaseline, and afterwards dusted with starch or oxide of zinc and starch (1 to 5 to 10), and then covered with cotton. The latter treatment is particularly good when blebs are present; they rapidly disappear under the application of desiccating substances such as unguentum diachylon or vaseline, or when dusted with starch and zinc oxide. But the cause of the erythema should always be taken into account, especially if it is a bacterial erythema—i. e., an erythema occurring in the course of an infectious disease.

2. **Eczema.**—Amongst the inflammations of the skin in which there is a formation of blebs special mention should be made of eczema, which is sometimes acute and sometimes chronic, and consists in the development of papules, vesicles, and pustules which dry and form crusts. The skin in the neighbourhood of the vesicles is usually more or less inflamed. Eczema, too, is particularly apt to be excited by all sorts of external irritation, such as wet antiseptic dressings of bichloride, carbolic acid, etc. A large number of very different skin diseases are included etiologically under the term eczema which should really be separated.

An important type of eczema is the *eczema seborrhoicum*, in which there is a formation of scales and crusts on those parts of the body which are richly supplied with sebaceous glands, such as the hairy portion of the scalp, the edges of the eyelid, the axilla, etc. (Unna).

Treatment of Eczema.—The treatment of acute eczema consists in removing the cause, such as the wet dressings, and then in the application of desiccating remedies—unguentum diachylon or vaseline, dusting with zinc oxide and starch, and covering with cotton, but without gutta percha over it, since the drier the eczematous area is kept the better. If success is not obtained by these methods, a trial should be made

with zinc glue (oxide of zinc and gelatine, each one part, glycerine and aq. destil., each four parts), Unna's ointment of benzoate of zinc spread on gauze, Pick's salicylic-soap plaster, Lassar's zinc paste, etc. Chronic eczema is treated in essentially the same way. In addition we use animal preparations—ichthyol (internally and externally), liniments which are allowed to dry on, etc. Pick's bichloride gelatine, the salicylic-soap plaster, Lassar's salicylic paste, Unna's salicylic-plaster mull, two to ten per cent. of chrysarobin or pyrogallic acid in vaseline, are all useful preparations. Arsenic should be administered internally, and in children oftentimes cod-liver oil. Any constitutional dyscrasiæ, such as gout, diabetes, scrofula, etc., should receive special treatment. The diet should be carefully regulated.

Other Skin Diseases.—According to the different forms and causes of erythema and the skin inflammations in which blebs develop, many varieties of these diseases are distinguished, such as erythema exudativum multiforme, erythema nodosum, urticaria tuberosa, impetigo (pustules drying and forming crusts), etc. We cannot discuss at this place other cutaneous affections like psoriasis (development of dry, white scales), prurigo (inflammation accompanied by the formation of papules), and the various manifestations of syphilis. By miliaria is understood an eruption of small, transparent vesicles; by herpes, vesicles arranged in groups—for instance, upon the lips (herpes labialis) or prepuce (herpes preputialis), and on the back (herpes zoster). Herpes zoster occurs along the distribution of some particular nerve, and is sometimes present when changes have taken place in the spinal ganglia and the Gasserian ganglion. The infectious character of herpes zoster is becoming more and more insisted upon; epidemics of this affection have repeatedly been observed (Pick, Kaposi). By pemphigus is understood a cutaneous eruption with the formation of blebs which vary in size from that of a pea to that of a hen's or goose's egg.

All moist cutaneous affections accompanied by the formation of blebs are best treated in the manner described above for eczema—viz., by desiccating dressings with oxide of zinc, or ointment dressings, such as unguentum diachylon.

3. **The Furuncle.**—By a furuncle is understood an acute inflammation of the sebaceous glands and hair follicles, which is always due to micro-organisms, especially the staphylococcus pyogenes aureus and albus (Garré). By the penetration of the micro-organisms into the mouths of the sebaceous glands there is first developed a pustule (acne) about the size of a pin-head, which soon enlarges into a very painful nodule the size of a pea or bean. After a few days suppurative softening usually develops in the centre of the nodule. Occasionally the inflammation extends more deeply and spreads into the surrounding parts, giving rise to a cellulitis with extensive suppuration or necro-

sis of the underlying fascia. Many people are very subject to furuncles. They sometimes develop simultaneously in various parts of the body in individuals who are otherwise perfectly healthy; the same thing also happens in diabetes, during the convalescence from typhoid fever, etc. It is interesting to note that during the furunculosis occurring in perfectly healthy people, sugar sometimes appears in the urine and vanishes after the recovery from the furunculosis. In hospitals where the antisepsis is defective furuncle epidemics sometimes arise.

Treatment of a Furuncle.—The best treatment of a furuncle is early incision under local anæsthesia with cocaine and the ether spray, to alleviate the painful tension and to provide an escape for the pus. Very often it is possible to prevent a furuncle from developing by opening the small acne pustule as soon as it forms and disinfecting it with a one-tenth-per-cent. solution of bichloride of mercury. In large, fully developed furuncles a cruciform incision should be made and the purulent masses carefully scraped out. Ointment dressings of boric-acid ointment or vaseline with iodoform are better than dry dressings. Much time used to be lost in the treatment of furunculosis by a purely symptomatic procedure, such as the employment of ice and warm, moist applications. When there is an extensive infiltration of the parts surrounding the furuncle, the moist, warm applications are no doubt serviceable; but the main point is always to lessen the tension by an incision at the earliest possible moment, and to provide a means of escape for the pus, in order to prevent the development of a cellulitis with extensive necrosis of tissue. Bidder has recommended as an abortive treatment for furuncles the parenchymatous injection of three per cent. carbolic acid.

The treatment for general furunculosis consists in the use of lukewarm baths, in regulating the diet, and in the internal administration of arsenic. The local treatment is in general the same as that given above. In diabetes, regulation of the diet is particularly important (meat, wine). It is well known that in diabetes extensive gangrenous processes sometimes occur in conjunction with a furuncle; in this condition the knife should be used with caution.

4. **Carbuncle.**—By carbuncle is understood a collection of furuncles lying close together, giving the skin the appearance of being perforated like a sieve by separate foci of inflammation. In this condition we generally have to do with infection by the staphylococcus pyogenes aureus and albus. The carbuncle has a more pronounced tendency than the furuncle to extend peripherally. It occurs particularly on the neck, back, buttocks, cheeks and lips. The carbuncle in healthy people, as a general thing, is not dangerous; but it can become com-

plicated with extensive phlegmonous suppuration and necrosis of the skin and deeper tissues, with venous thromboses, and may terminate fatally from septicæmia or pyæmia. In a carbuncle involving the lips, cheeks, or neck, there is reason for fearing an extension of the inflammation to the cranial cavity, as cases in which this happens often run a rapidly fatal course. When the patient has diabetes the gangrenous destruction of tissue is often very considerable, and not infrequently, as a result of the extensive gangrene. and in spite of energetic and suitable local surgical treatment, death will occur from sepsis or pyæmia.

The Treatment of a Carbuncle is essentially the same as for a furuncle, and the incisions should be made as early as possible. Their number will depend upon the extent of the inflammation, though in small carbuncles it is sufficient to make one longitudinal or cruciform incision down to healthy tissue. If the suppuration and necrosis of the tissues are sufficiently far advanced, I remove the softened gangrenous and suppurating parts with a sharp spoon, scissors, and forceps, and disinfect the focus most carefully with a one-tenth-per-cent. solution of bichloride of mercury. For dressings I prefer iodoform, dermatol, or zinc oxide with boric ointment or vaseline. Moist warm applications are excellent for softening areas containing an inflammatory infiltration. Later on we should always be on the alert to prevent any burrowing of pus, any retention of the discharges, etc. According to the extent of the inflammation, the antiseptic dressing should be changed once or twice a day, or every two to three days. This energetic operative treatment of a carbuncle is better than the old-fashioned symptomatic method, which avoided the use of the knife. The strength of old people, in particular, should be sustained by nutritious food, by wine, etc. Cutaneous defects—loss of skin substance on the face, for example—should be remedied by plastic operations.

The anthrax carbuncle (*pustula maligna*) is described in § 77, and acute inflammation of the skin and cellular tissue (Cellulitis) in § 70.

5. **The Chronic Inflammations of the Skin and Subcutaneous Cellular Tissue—Lupus.**—Of the chronic inflammations of the skin I shall first take up lupus, a disease which is to be regarded, in the main, as a tuberculosis of the skin (see § 83). As a proof of this, tubercle bacilli are found in the lupus foci (see page 408). By the inoculation of lupous tissue into the peritonæum or the anterior chamber of the eye of guinea-pigs and rabbits unquestionable typical tuberculosis is produced. As regards the pathological changes in lupus, I must refer the reader to the detailed description of tuberculosis in § 83; we shall discuss here only the following clinical aspects of the disease. Lupus is particularly apt to occur on the face, though it also appears on

other portions of the body, such as the extremities. Lupus originates by the tubercle bacilli finding lodgement in the normal pores of the skin, or in some wound which may be a very small cutaneous injury or an abrasion. Not infrequently it may be proved to have originated by inoculation or by contact with people having tuberculosis. This lupus coming from inoculation, as a result of a direct infection, and occurring in individuals otherwise perfectly healthy, I believe to be much more common than has hitherto been supposed. In lupus of the skin the pathological changes consist in the formation of small nodules made up of typical tubercles. The nodules may disappear by absorption, or break down and suppurate, giving rise to corresponding losses of substance in the skin—i. e., ulcers. In combination with the nodules and ulcers a diffuse infiltration and hyperplasia of the tissues is frequently observed. The epithelium often proliferates in an atypical form growing into the subcutaneous cellular tissue and giving rise to formations similar to carcinoma.

Fig. 313.—Lupus of the face (Esmarch).

As regards further pathological changes in lupus, I must refer the reader, as I have before remarked, to the detailed description of tuberculosis in § 83. We shall confine ourselves here to its clinical and therapeutic aspects.

Clinically, three forms are distinguished: lupus maculosus (or lupus exfoliativus), lupus exulcerans, and lupus hypertrophicus. In *lupus maculosus*, red or yellowish-brown smooth spots are formed, with a cracked, exfoliating, epidermic covering (lupus exfoliativus). If there is destruction of tissue, corresponding ulcers result, generally covered with crusts (lupus exulcerans), which may lead to extensive destruction of the skin and adjoining parts, especially upon the nose, cheeks, lips, etc. (Fig. 313). Very often the process extends at the peripheral portion of the diseased area, while in the centre a smooth or seamed cicatricial tissue develops. In lupus exulcerans there will be found, in addition to the tubercle bacilli, pus cocci, especially the staphylococcus pyogenes aureus. According to Leloir and Tavernier, the ulcerative changes occurring in lupus are mainly due to the pus cocci which come from without. Cazin describes hyaline flakes in the connective tissue of ulcerating lupus.

They take on a deep stain, with crystal violet (according to Kühne), and are similar to the bodies found by Russel in epitheliomata. The nodular form of lupus is called lupus hypertrophicus (Fig. 314). Between these different classes there are numerous transition forms, which often occur close beside one another in the same lupous collection. The clinical course of lupus is usually very chronic. It generally begins in children from four to twelve years of age, or later, and often lasts for many years. In consequence of the losses of substance and marked cicatricial shrinkage or diffuse cicatricial thickening, bad deformities result, particularly on the face (Fig. 315,) the treatment of which will be discussed in the Special Surgery. Not infrequently patients with lupus die of tuberculosis of the internal organs—of the lungs, for example. Sometimes epitheliomata originate in lupous foci and cicatrices.

Fig. 314.—Lupus hypertrophicus of the hand (Busch).

Treatment of Lupus.—The treatment of lupus consists, in addition to a suitably invigorating mode of life (see § 83, Tuberculosis), mainly in adopting energetic local surgical measures, such as excision of the lupous disease or its destruction with the sharp spoon (Volkmann, page 72), the Paquelin thermo-cautery (see page 74), or the galvano-cautery (see page 76). The earlier a lupus is removed by extirpation with the knife the sooner may permanent recovery be expected. The wound from the excision is either simply closed by sutures, or, if this is impossible on account of too great a loss of substance, the cutaneous defect is remedied by plastic operations (see page 134), or by Thiersch skin grafts (see page 141). The plastic operation or transplantation of skin prevents the troublesome consequences produced by cicatricial contraction, and is especially valuable in preventing recurrences. By excision of the lupus and making use of Thiersch skin grafts, particu-

Fig. 315.—Lupus (Esmarch).

larly on the face, I have obtained very satisfactory results and have prevented or overcome bad deformities. Punctures made with a galvano-cautery curved at the end, or with the fine tip of the Paquelin cautery, are exceedingly serviceable for the pure macular or exfoliating lupus, such as occurs upon the face. We destroy lupus exulcerans or hypertrophicus by vigorous scraping with the sharp spoon, or by using the Paquelin thermo-cautery, in case excision is impossible. I have given up the use of caustics altogether (caustic potash, copper sulphate, nitric or chromic acid, etc.). Liebreich recommends the subcutaneous injection of cantharidic acid or of the cantharidate of potassium. It is my opinion that the treatment of lupus by ointments is entirely without effect. The constitutional treatment by strengthening food, good air, sea baths, proper climate, etc., is, next to the energetic local treatment, of the greatest importance, especially for preventing any recurrence of the disease. The treatment of lupus by Koch's tuberculin is described on page 421. Actual cures by tuberculin are rarely obtained; I have never seen one. In the course of the treatment, after apparent improvement has occurred in the affected portion of skin, I have excised a piece of the latter and found in the deeper parts, under the healed external cutaneous covering, eruptions of new tubercles.

6. **Ulcers of the Skin.**—By ulceration is understood a granulating defect in the skin accompanied by a suppurative breaking down of the granulations, which shows no tendency to heal. Ulcers present great differences as regards their size, character, and course. The causes of an ulcer, its location, and the general condition of the patient, have a most important bearing upon its clinical course. According to the intensity of the reactive inflammation, we make a distinction between atonic or torpid ulcers and inflammatory ulcers. There are great differences in the shapes of ulcers, some being round, others half-moon shaped, circular, or irregular in outline. The surface of an ulcer may be smooth or sunken, or more or less prominent. According to the character of the surface of the ulcer or its base we distinguish œdematous, hæmorrhagic, gangrenous, sloughing, and fungous ulcers; the latter are marked by prominent, spongy, inflamed granulations. Very often a canal, or fistula, as it is called, extends from the ulcer to a greater or less depth into the adjoining parts. The fistulæ (from *fistula*, a pipe), as a general thing, originate from some deeply placed focus of inflammation which has gradually made its way to the surface. The edges of an ulcer may be either more or less normal, flat or swollen, or hard and like a wall (callous ulcer), or undermined (sinuous ulcer). Phagedenic ulcers (*φαγέδαινα*, from *φαγεῖν*, to eat) are those

which increase more or less rapidly in circumference analogously to the hospital gangrene of wounds (see § 72).

The causes of ulcers are very numerous, and are sometimes local and sometimes constitutional. Ulcers originate from traumatisms of various descriptions, from stasis, or from the suppurative breaking down of tumours and products of inflammation, such as syphilis (§ 84), tuberculosis (§ 83), lupus and leprosy (§ 85). The varicose ulcer of the leg, of so common occurrence, develops from inflammatory stasis in the leg in conjunction with dilated veins (varices, Fig. 316). When varices exist, any mild inflammation, a slight traumatism, or an eczema vesicle may, as a result of the venous stasis, give rise to an ulcer, since repair or the formation of normal granulation tissue is rendered difficult by the disturbance in the circulation. Ulcers may also originate when in any portion of the body a necrosis of the skin is brought about by pressure. In this class belong the bedsores which occur upon the sacrum, over the trochanters, on the heel, etc., in individuals whose nutrition is impaired and whose circulation, as a result of anæmia and cardiac weakness, is imperfect. Trophoneurotic gangrene and ulcerative processes occur in paralytic conditions and other diseases of the nervous system. Great interest attaches to the often multiple, neurotic ulcers of the skin occurring in conjunction with gangrene of the skin, as a result of ascending neuritis with secondary disease of certain central portions of the spinal cord (Doutrelepont, Kopp, and others). The soft and hard chancres have been mentioned in § 84.

Fig. 316.—Varicose ulcer of the leg (*a*), resulting from varicose veins.

Treatment of Ulcers.—The treatment of ulcers varies with their cause. The latter must always be carefully taken into account if an ulcer is to be properly treated; for example, a constitutional dyscrasia, like syphilis, tuberculosis, or bad nutrition, nervous diseases, etc., must at the same time be attended to. The treatment of every ulcer should be conducted upon antiseptic principles. Dressings with iodoform, dermatol, oxide of zinc, bismuth, naphthaline, with or without ointments (boric-acid ointment), are excellent. The numerous antiseptic

materials for covering a wound (powder, ointments, etc.) are enumerated in §§ 45, 46. Gangrenous phagedenic ulcers are best treated by scraping them with a sharp spoon, by cauterisation with caustic potash, the Paquelin or galvano-cautery. In large ulcers the use of permanent irrigation (page 178), or a bath for the entire body (page 179), are sometimes advantageous. It is very important to prevent any stasis, any disturbance of circulation, by placing the parts in a suitable position, by rest, etc. For varicose ulcers of the leg, satisfactory results are often obtained by enveloping the leg in Martin's elastic bandage, which possesses the great advantages of not confining the patient to bed and of allowing him to attend to his business. Not infrequently, however, Martin's elastic bandage is not well borne, as it excites a persistent eczema, which should be treated as described on page 512. If the borders of the ulcer are slightly movable, *circumcision* of the ulcer is an excellent means of making it possible for the base of the ulcer to contract, thus hastening the healing (Nussbaum). The circumcision is performed by carrying an incision through the skin down to the fascia, around the ulcer some one to two to three centimetres from its edge. For hastening the growth of skin over the ulcer, Thiersch's method of skin grafting (§ 42) is particularly serviceable after previously freshening or scraping off the base of the ulcer with a sharp spoon. Circumcision of the ulcer can be combined to good advantage with skin grafting. The latter procedure has taken the place of the implantation of skin flaps with pedicles taken from immediately adjoining or distant portions of the body, and which were formerly much in vogue. Maas in particular has obtained good results from the implantation of pedunculated skin flaps taken from a distant portion of the body. He recommends that the flap to be transplanted be cut as much as possible in the direction of the course of the vessels, and, after previously removing the layer of granulations in the defect with a sharp spoon, the edges of the ulcer should be freshened all around ; the flap is then united by sutures to the borders of the defect and by buried sutures to its surface. The wounded and exposed portion of the flap is prevented from drying by being covered with a plentiful amount of boric-acid ointment spread on gauze. An antiseptic dressing is placed over everything, and the portions of the body under treatment are completely immobilised by a plaster-of-Paris dressing. Whenever possible, the dressing is left undisturbed for fourteen days and then the pedicle of the flap is divided. In this way a flap can be transplanted from the breast to the arm, from one leg to the other, and from the upper extremity to the face, and joints can thus be made movable which were previously stiffened by cicatricial contractures—i. e. had lost their func-

tion. In conclusion, I should mention that hypertrophic bone under the base of an ulcer—in the tibia, for example—must be carefully levelled off with the chisel; any undermined borders around an ulcer should be excised, fistulæ should be laid open, etc. In many cases of extensive ulceration, when repair is impossible or the affected limb is useless, amputation may be indicated. It should be borne in mind that, as a result of the exposure and erosion of a vessel by an ulcer, a serious or even fatal hæmorrhage may occur, unless aid can be speedily obtained.

Scurvy (Scorbutus) and the Ulcers which occur with it.—Ulcers also occur in scurvy, especially on the gums, in the upper portion of the cavity of the mouth, and on the lips. The gums swell as a result of hæmorrhages, become bluish red, and then break down into peculiar bluish-red ulcers with bluish-green borders and granulations, which bleed easily. In other respects scurvy is characterised by hæmorrhages into the skin and the subcutaneous cellular tissue (purpura scorbutica), into the muscles, joints, and from the intestine, by general emaciation, anæmia, and hydræmia. Scorbutus now occurs less often than formerly. It is to be regarded essentially as a severe cachexia, or a general disturbance of nutrition, involving particularly the walls of the blood-vessels. Whether micro-organisms play any part in the origin of scurvy is still a matter of uncertainty. The disease occurs endemically, especially among individuals who live under unfavourable external conditions, such as sailors who have eaten for a long time only salted meat without any fresh vegetable food. It also occurs in damp, badly ventilated and crowded quarters (prisons, barracks, etc.). Scorbutus has only a slight interest for the surgeon, so that we must refer the reader to the text-books on internal medicine. The prognosis of this affection, which for the most part runs a chronic course, depends upon the possibility of speedily removing the unfavourable hygienic conditions. Hence the treatment consists mainly in providing good dwellings and good food (fresh meat, fresh vegetables). In addition to this, acids—particularly vegetable acids—are beneficial in the form of fresh watercress and sorrel. Since legislation has provided that ships, prisons, etc., should be well supplied with food, and that the inmates of prisons obtain fresh vegetables in sufficient quantity, scurvy has become less common. The ulcers in the mouth should be treated by mild cauterisation with nitrate of silver, iodoform, and gargles of three-per-cent. chlorate of potash or boric acid.

Other Anomalies of Granulating Wounds.—In addition to the ulcerative destruction of granulations there are still other anomalies of granulating wounds which interfere with their healing, and these we shall discuss briefly. By fungous or spongy granulations are understood those which project above the level of the surface of the wound in the form of a fungus. Soft, luxuriant granulations like these are observed in tuberculosis especially, and also when there are any hindrances to healing, such as those due to induration of the surrounding parts, or to the presence of a foreign body, or a necrotic piece of bone—a sequestrum, as it is called—in the depths of the wound. The treatment of these fungous granulations consists in removing the above-mentioned causes and in applying energetic cauterisation with the nitrate-

of-silver stick. Pressure also does good service. When necessary, the granulations may be removed by a sharp spoon, the thermo-cautery, or simply by the knife or scissors, and the wound surface covered with very small pieces of skin by Thiersch's method (§ 42).

Irritable Ulcer.—By *irritable* ulcer very painful granulations are meant, which bleed easily. It is not known upon what the painfulness of these granulations really depends, and it is the more remarkable from the fact that granulation tissue usually possesses no nerves. The affection is observed most commonly in anæmic or hysterical individuals. The best treatment consists in the application of desiccating powder dressings (iodoform, bismuth, dermatol), or in the removal of the painful granulations by caustics, or, better, with scissors or the sharp spoon, followed by transplantation of skin, etc.

7. **Elephantiasis.**—By elephantiasis (elephantiasis Arabum or pachydermia acquisita) is understood an extensive hyperplastic thickening of the skin and subcutaneous cellular tissue over large portions of the body, most frequently observed upon the lower extremities and genitals (Fig. 317). The hyperplasia of the tissues may develop in conjunction with various chronic and frequently recurring inflammations, such as chronic eczemas, ulcerations, chronic periostites and osteomyelites, erysipelatous and lymphangitic processes, lymph stasis, injuries to nerves, etc. A second form of elephantiasis is the result of a chronic affection, the nature of which is still unknown, and occurs endemically in tropical and subtropical countries (Central America, Arabia, India), while in Europe only sporadic cases are observed. In its epidemic form the process is due in many instances to the presence of the filaria Bancrofti (or medinensis), which, with its embryos, inhabits the lymphatic vessels and causes lymph stases and inflammations, particularly of the external genitals, the thigh, and peritoneal cavity. The invasion of the filaria does not in every case give rise to elephantiasis, and as a matter of fact the parasites have not been found in the majority of cases. The thread-like worm is 8 to

Fig. 317.—Elephantiasis of a native of Samoa; removal of the scrotum, which weighed seventy-eight pounds, followed by recovery. (Königer.)

10 centimetres long, and its larvæ about 0·35 millimetres. They probably enter the human organism, the lymphatic vessels, and the blood from the intestine (Manson, Scheube).

The portions of skin involved in the elephantiasis are sometimes dense and hard (elephantiasis dura) and sometimes made up of soft, greyish-white tissue (elephantiasis mollis), and often contain greatly dilated lymphatic vessels (elephantiasis lymphangiectatica). Elephantiasis is occasionally congenital, and may be a result of abnormal development and new formation of blood and lymphatic vessels (elephantiasis congenita telangiectodes and E. lymphangiectodes). (See also Tumours.) In rare instances an inherited elephantiasis is observed, which, according to Nonne, is probably the result of an inherited defect in the development of the lymphatic system.

Treatment of Elephantiasis.—The treatment of elephantiasis in the beginning of the disease is directed towards the cause, particularly the inflammatory changes in the affected portions of the body. Enveloping the parts in elastic bandages, placing them in an elevated position, injections of alcohol, ligation of the main afferent artery, punctate cauterisation, repeated spindle-shaped excisions, and total removal of an elephantiatic scrotum or of the affected extremities by amputation or disarticulation, have all been employed (see Special Surgery).

8. **Myxœdema.**—Myxœdema is a very rare, easily recognised affection of great pathological interest. The disease, which was first described by Gull in 1873 as the "cretinoid condition," affects women more often than men, especially those of middle age. There is always a destructive change, such as fibroid degeneration, interstitial connective-tissue development, or other disease of the thyroid gland, the latter being sometimes enlarged and sometimes atrophic. Myxœdema has also been observed in connection with syphilitic disease of the thyroid gland. The interstitial connective-tissue growth generally present in the thyroid is mainly the result of an inflammatory process, and is also very frequently found in the skin and in the internal organs. A pronounced excess of mucin is found in the skin and blood; the amount of hæmoglobin in the blood is diminished, while the amount of red corpuscles and fibrin varies, being sometimes diminished and sometimes increased. The power of the red blood-corpuscles to take up oxygen may be greatly diminished. The skin, particularly of the face and extremities, is characteristically swollen. There are also disturbances of speech, of motion, and of intellect, and, in brief, a remarkable decline of the bodily and mental functions. In youthful individuals the normal development does not take place (dwarfs, etc). Myxœdema is extremely rare in childhood.

By experimental extirpation of the thyroid gland in animals, and by its total extirpation in man, there is produced a form of disease, the so-called cachexia strumipriva or thyreopriva, which corresponds in all respects to myxœdema, and hence only a *partial* removal of the thyroid gland is allowable in man. Myxœdema has also been observed after partial extirpation of the degenerated gland when the retained portion atrophied with remarkable rapidity (Köhler). Schiff and Eiselsberg demonstrated that animals withstand total extirpation of the thyroid gland if their own thyroid gland, or one taken from another animal of the same species, is successfully implanted in the peritoneal cavity and resumes its normal function there. The function of the thyroid gland, which is to prevent the accumulation in the body of mucin, is disturbed in myxœdema. Therefore myxœdema may originate from operative removal as well as from degeneration of the thyroid gland, and is probably identical with the so-called sporadic cretinism which occurs in children, and is closely related to endemic cretinism. The ultimate causes of degeneration of the thyroid gland are unknown. Myxœdema usually terminates fatally in a few years. According to Bircher and others, myxœdema and cretinism are, in respect to their etiology, pathogenesis, and course, totally different processes. As regards treatment, Horsley recommends the implantation of the thyroid gland after total extirpation of the gland, and for myxœdema. In one case of myxœdema, which had existed for four to five years, Murrey obtained remarkable improvement by ten injections of the extract from two and a half thyroid glands taken from sheep.

Scleroderma.—By scleroderma is understood a circumscribed or more diffuse hardening of the skin, occurring rather suddenly in adults, without external causes, and either remaining stationary or gradually extending, and finally terminating in atrophy. In scleroderma the skin is as hard as wood, and the disease occurs on the trunk, the face, and the extremities. Its nature is unknown. Anatomically, Chiari found a thickening of the fibrous stroma of the skin combined in places with an infiltration with leucocytes. In one case Heller found obliteration of the thoracic duct.

Scleroderma neonatorum, according to Langer, is caused by a stiffening and hardening of the subcutaneous cellular tissue in conditions of collapse and lowered body temperature.

Idiopathic Atrophy of the Skin.—Idiopathic atrophy of the skin is an exceedingly rare disease, and the etiology is obscure. Sometimes excessive cold or heat, nervous influences, etc., appear to be the cause. The atrophic areas of skin slowly increase in circumference, and eventually lead to corresponding disfigurements. As yet it has been impossible to find a successful treatment.

Dermatolysis.—In the so-called dermatolysis (Tilbury, Fox), the skin, without apparent change in structure, becomes too abundant and loose, giv-

ing rise to folds. The faces of youthful individuals may thus assume an aged expression.

For tumours of the skin, see Tumours, §§ 125–130.

§ 94. **Inflammations and Surgical Diseases of the Mucous Membranes.** —*Diseases of Mucous Membranes of Surgical Importance.*—Brief mention will be made here only of those diseases and inflammations of mucous membranes which are the object of surgical treatment. We shall discuss injuries in the Special Surgery. As a general rule, wounds of mucous membrane, if strict asepsis is observed, heal readily, particularly under the use of iodoform.

Acute Inflammation.—Acute inflammation of the mucous membranes occurs as an acute catarrh or acute catarrhal inflammation which is characterised by hyperæmia, œdematous swelling, and the formation of a discharge at first poor in cells and then containing large quantities of them. Some of the cells are extravasated colourless blood-corpuscles, and others desquamated epithelium. Not infrequently in catarrh there is a development of vesicles and superficial losses of substances—catarrhal ulcers. The causes of catarrhs may be mechanical or chemical in nature, or, what is most common, they may be due, in the main, to micro-organisms, as is, for instance, the acute catarrh of the mucous membrane of the genitals—gonorrhœa (see page 433). Catarrhs which occur as a result of chemical irritations are produced, for example, by the action of mercury or iodine; many individuals are very susceptible to these two substances. The acute inflammations which follow the use of mercury and attack the cavity of the mouth, for example (stomatitis mercurialis), are occasionally observed during the treatment of a wound with bichloride, or during the inunction treatment of syphilis, etc. (see page 434). Mercurial stomatitis is characterised by a swelling of the gums, salivation, swelling of the mucous membrane of the mouth at various points, and the formation of ulcers. Mercurial stomatitis, as we shall see, is best prevented by cautious use of bichloride in the treatment of wounds, by paying careful attention to the cleanliness of the mouth, by stopping smoking during the inunction treatment, etc. The treatment of the mercurial stomatitis itself consists in gargling the throat with chlorate of potash or boric acid. This complication can usually be speedily cured by superficial cauterisation of the ulcers with silver nitrate or copper sulphate in substance, and also by stopping the bichloride dressings or the inunctions.

Cancrum oris or *noma* is a severe ulcerative stomatitis, which will be discussed in the Special Surgery, with the other diseases of mucous membranes in the facial cavities, the digestive tract, genito-urinary apparatus, etc.

Croupous and Diphtheritic Inflammation.—By *croup* and *diphtheria* inflammatory processes are understood which are for the most part identical pathologically and clinically, and only differ in degree. Both inflammations are characterised by the formation of an inflammatory product consisting of fibrin and cells, which is slightly adherent to the surface of the mucous membrane. In croup (Fig. 318) the membrane lies upon the mucous membrane, while in diphtheria the exudate is also found in the mucous membrane, and the latter becomes more or less necrotic (Fig. 319). In the formation of this pseudo-membrane, according to Baumgarten, the "fibrinous" degeneration of the epithelium plays an important part as well as the fibrinous exudate. In croup there is a fibrinoid degeneration of the epithelium only, but in diphtheria this process also involves the connective tissue. The local death of tissue produced by the diphtheritic inflammation is, according to Cohnheim and Weigert, a coagulation necrosis—i. e., a death of the tissues and cells due to the coagulation of lymph which permeates the affected tissues and penetrates into the cells. The croupous and diphtheritic membranes come away after a certain length of time, being cast off by the new epithelium which is produced underneath and pushes the remains of the membrane before it; in severe cases the membrane comes away *in toto* (Heubner). Croup can be excited experimentally by the injection of liq. ammonii caustici into the trachea of a rabbit, the animals usually dying in two to three to four days with symptoms of asphyxia. There is no *anatomical* distinction between this experimental croup and

Fig. 318.—Croupous membrane (*B*) upon a mucous membrane (*Sch*), consisting of a network of fibrin which is filled with leucocytes. × 150.

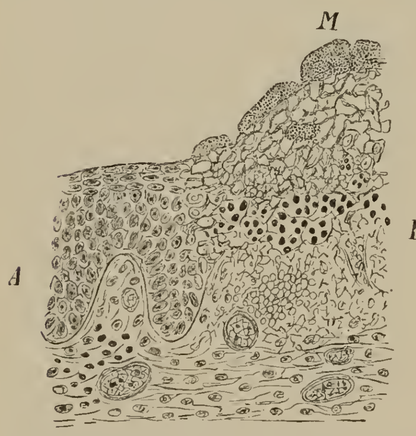


Fig. 319.—Section through the uvula in diphtheritis faucium at the border of the healthy tissue: *A*, normal epithelium and submucous tissue; *B*, the connective tissue underneath the epithelium and mucous membrane infiltrated with fibrin, leucocytes and red blood-corpuscles; *M*, masses of micrococci. × 120.

epidemic diphtheria (Middeldorpf, Goldmann). The pharynx and trachea are most frequently affected by the croupous and diphtheritic inflammation; less often the mucous membrane of the bladder and intestine. Diphtheria occasionally occurs in the skin, starting, for example, from infection through a cutaneous abrasion or wound, especially in the neighbourhood of mucous membranes such as that of the female genital tract, the rectum, etc. True diphtheria is an infectious disease which is produced by a specific bacillus discovered by Löffler, and is to be carefully distinguished from all other pathological processes which are likewise accompanied by the formation of croupous or diphtheritic changes in the mucous membranes and do not differ *anatomically* from true diphtheria (so-called pseudo-diphtheria). By temporarily interrupting the circulation of blood in the urinary bladder Heubner excited artificially a local pseudo-diphtheria of this description which was not transmissible to animals by inoculation like true diphtheria. In true diphtheria there develops, as a result of the absorption of the poisonous products of the bacterial metabolism, a febrile systemic intoxication the severity of which varies greatly, though it very often speedily terminates in death, particularly when a degeneration of the muscles of the heart takes place. Amongst other sequelæ of diphtheria, nephritis (albuminuria) and paralyses are especially prominent. In the latter there occur histologically pronounced inflammatory changes in the muscles and nerves (Hochhaus). The symptomatology of diphtheria is discussed in the Special Surgery. See also Wound Diphtheria, § 72.

The Etiology of Diphtheria—Löffler's Diphtheria Bacillus.—Löffler was the first to prove the constant presence of a species of bacteria in human diphtheria; he cultivated it artificially and inoculated animals with it. It was impossible to excite genuine diphtheria in animals, but Löffler was able to prove that the bacteria in question had pronounced poisonous properties. Fränkel and others have confirmed Löffler's statements, and Roux and others successfully inoculated animals with Löffler's bacillus and observed the symptoms which are peculiar to human diphtheria, particularly the formation of local diphtheritic processes and the paralyses which follow the general intoxication. Upon the basis of these facts, we are justified in the belief that Löffler's bacillus is the actual excitant of diphtheria.

The diphtheria bacilli are small rods about as long as tubercle bacilli, though almost twice as thick, of a plump appearance, and generally with rounded ends (Fig. 320). They vary, however, greatly in their form, the rods having frequently a club-shaped thickening at the end, while others are in process of division into several pieces by transverse segmentation (manifestations of involution). The bacilli are found in the diphtheritic pseudo-membrane, and nowhere else in the body; consequently the severe constitutional symptoms of diphtheria are caused by the exceedingly poisonous prod-

ucts of their metabolism. Opinions vary as regards the nature of the toxines of the diphtheria bacilli, though they are generally considered to be albuminoid bodies belonging, according to Brieger and Fränkel, to the toxalbumens, according to Roux and Yersin to the diastases, and according to Gamaleia to the nuclein compounds. They are formed either by the decomposition of the albuminous bodies contained in the nutritive substances, or the microbes develop them within themselves by synthesis of simpler bodies (Guinochet, Strauss). The toxic substances of the diphtheria bacilli are marked by a certain instability being destroyed by heat and ferments (pepsin, pancreatin), and passing through the digestive tract without causing any disturbance (Gamaleia). The diphtheritic poison is decidedly weakened by antipyrin (Vianna). Mixed (septic) infections originate from the presence at the same time of streptococci and staphylococci.

Fig. 320.—Bacilli of diphtheria, × 1200: *a*, young bacilli from a fresh culture; *b*, involution forms (Löffler).

The bacilli are facultative anaërobic, and incapable of movement; they grow at temperatures ranging between 68° and 104° F. upon gelatine or other nutritive medium, which must always be made slightly alkaline, and especially well upon Löffler's blood serum (three parts blood serum from cattle or sheep, one part beef bouillon, one per cent. peptone, one half per cent. common salt, one per cent. grape sugar) and upon glycerine-agar. On Löffler's blood serum a thick, glistening, whitish scum forms in the incubator at a temperature of 98·4° F. in about two days. On glycerine-agar at the incubator temperature, flat, greyish-white, glistening colonies, with smooth edges, the size of a millet seed, develop within twenty-four to forty-eight hours (Fig. 321). On agar the cultures at first grow slowly, but the second generation more luxuriantly, as the bacilli have then become accustomed to the nutritive medium, which was not at first suited to them. But at the same time they suffer a loss in virulence. When stab cultures are made in gelatine, small white globular colonies develop along the inoculated line of puncture. On gelatine plates, at a temperature of 22° to 24° C. (71° to 75° F.), the colonies remain small and the gelatine is not liquefied. The bacillus grows upon potatoes provided the surface is made alkaline; milk is also an excellent nutritive medium. At temperatures ranging from 45° to 50° C. (113° to 122° F.) the bacilli perish. Spore formation has not been observed. The bacilli are also possessed of great powers of resistance; they will remain in a dried pseudo-membrane and be capable of development after the lapse of three to four months. Roux and Yersin demonstrated that serum cultures, under ordinary conditions, retain their vitality and virulence for five mouths; and, furthermore, that the cultures kept entirely shut off from the action of air and light still possess their full virulence after the lapse of thirteen months.

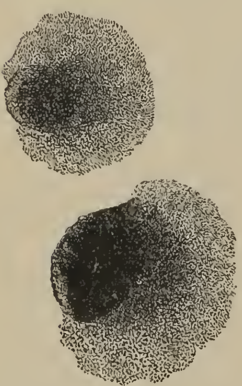


Fig. 321.—Diphtheria bacillus. Colony upon agar, twenty-four hours old, unstained, × 100 (Fränkel and Pfeiffer).

The diphtheria bacilli can be best stained with Löffler's alkaline methyl blue solution; they do not stain by Gram's method. But, according to the

recent investigations of Roux and Yersin, the latter method can also be easily used. The virulent diphtheria bacilli are almost never found in the mucus of the mouth of a man who is healthy or who has some other disease, but Löffler and Hofmann state that pseudo-diphtheria bacilli are often found which are very similar but have no pathogenic action, and are to be regarded as possibly weakened forms of the diphtheria bacilli.

Transmission of Diphtheria to Animals.—Inoculations in animals are often unsuccessful; guinea-pigs, rabbits, doves and chickens are particularly susceptible, while mice and rats are not very much so. In guinea-pigs, doves, etc., the cultures excite pseudo-membranes in the trachea, and sometimes severe constitutional symptoms, paralyses, etc. Guinea-pigs are the most susceptible; within a few days after subcutaneous inoculation they die with œdema, pleuritic effusions, etc., but the bacilli are not found in the internal organs. Filtered cultures, or the poisonous albuminous bodies (toxalbumens) isolated from the cultures excite severe symptoms of intoxication, which, however, take a long time to cause death.

Artificially Acquired Immunity from Infection by Diphtheria.—Behring and Kitasato have made animals artificially immune from diphtheria (1) by the use of cultures sterilised by Fränkel's method; (2) by the addition of iodoform to the cultures; (3) by subcutaneous and intra-abdominal injection of the pleuritic exudate which frequently forms in diphtheritic animals; (4) by subcutaneous injection of iodoform very soon or a few hours after the infection with diphtheria. It is also possible to give animals an increased power of resistance against diphtheritic infection by the administraion of peroxide of hydrogen for a few days before the infection. By inoculating guinea-pigs with sterilised culture fluids heated for a few hours to between 60° and 70° C. (140° and 168° F.), C. Fränkel obtained immunity after the lapse of fourteen days. Two kinds of substances are found in the culture fluids of diphtheria bacilli—viz., a toxic substance which is destroyed when heated to 55° to 60° C. (131° to 140° F.), and an immunising substance. According to Behring and Kitasato, the animals which have been rendered immune are not only protected from infection with living diphtheria bacilli, but also from the injurious effects of the poisonous products of their metabolism. Nevertheless, the immunity may be again lost by repeated injections of considerable amounts of poison, especially if the immunity has not been sufficiently firmly established. The artificially acquired insusceptibility to diphtheria depends upon changes in the serum of the blood of the animals in question. Behring has consequently recommended the subcutaneous injection of this immunising serum as a therapeutic measure for diphtheria in man. No definite judgment can be pronounced as yet upon the success of this method of treatment.

Spread of Diphtheria.—The bacillus of diphtheria varies in the degree of its virulency at different times. This explains why the course of diphtheria in different cases and in different epidemics is so dissimilar. Diphtheria spreads by contagion; the membranes which are coughed up, the sputa and the saliva are the most common sources of infection. During convalescence the bacilli remain alive in the mouth for about three weeks; in a dried condition they may persist in thick layers for three to four months, and in a half-dried condition for seven months. Toys, eating and drinking utensils,

kissing, etc., sometimes cause the spread of the disease. An ectogenous development of diphtheria bacilli sometimes takes place in articles of food, such as milk. The individual predisposition to diphtheria decreases very much after the thirteenth year. A pharyngeal mucous membrane affected with or having a tendency to catarrh is a favourable soil for the lodgement of the diphtheria bacillus. To prevent the starting and spread of diphtheria, the patients should first of all be strictly isolated in every respect, and objects coming in contact with them should be properly disinfected.

Other Bacteria Streptococci and Staphylococci present in Diphtheria.—In addition to the diphtheria bacilli there are very frequently—in fact almost always—found streptococci. These appear to have no bearing upon the diphtheria as such, but may give rise to general septic infection—mixed infection (Beck, Barbier, etc.). But, according to Baginsky, there is a form of diphtheria which clinically is like true diphtheria, but is not dangerous, and terminates in recovery ; in this Löffler's bacillus is not present, and Baginsky only found streptococci and staphylococci.

The Pseudo-Diphtheria Bacillus.—In addition to the diphtheria bacillus, which is the excitant of true diphtheria. Löffler and others have described a pseudo-diphtheria bacillus which is morphologically and biologically slightly different from the true diphtheria bacillus. It is somewhat shorter and thicker, grows luxuriantly at a temperature of 20° to 22° C. (68° to 72° F.) in bouillon, and changes the reaction of bouillon more rapidly, forms upon serum a more yellow scum, and does not thrive as well in the absence of air as the true diphtheria bacillus. When inoculated in animals, local manifestations are sometimes observed, but death never occurs (Roux, Yersin). The pseudo-diphtheria bacillus is found in the mouths of healthy individuals, and in simple sore throats. According to Roux and Yersin, a certain relationship exists between the two kinds of bacilli. They succeeded in permanently changing very virulent true diphtheria bacilli, by the action for several days of a steady stream of air, to such an extent that they behaved like pseudo-diphtheria bacilli; and on the other hand, by simultaneous inoculations with erysipelas cocci, they were able to restore to the weakened diphtheria bacilli their full virulence, but not to the pseudo diphtheria bacilli.

§ 95. **Inflammations and Diseases of Blood-vessels.**—The acute inflammations of the arteries and veins—arteritis and phlebitis—have been described in § 69 and § 75 (pyæmia); and the various changes which thrombi undergo, including the cicatricial closure of a vessel, the so-called organization of a thrombus, were discussed in § 61. There remains for us to take up chronic inflammations of the walls of the vessels, as well as aneurysms and varices.

Chronic Inflammations of the Walls of the Vessels.—The fatty, amyloid, and hyaline degenerative changes occurring in vessels belong more to the domain of pathological anatomy, but hypertrophic conditions in the arteries have also a surgical importance. The development of the collateral circulation after occlusion of a vessel or the formation of an aneurysma racemosum (see Aneurysms) depends upon a

hyperplasia of all the arterial coats. Chronic endarteritis is particularly important; it consists in a hypertrophy of the intima from a circumscribed or more diffuse growth of connective tissue. In this class belongs the endarteritis obliterans of syphilis, for example, and endarteritis deformans (arterio-sclerosis or atheroma). Nodular or more diffuse thickenings of the arteries develop from inflammations in the parts surrounding the arteries—in other words, from periarteritis. Phlebitis hyperplastica and periphlebitis chronica are much rarer than chronic arteritis, and the pathological changes are not by any means so pronounced.

Endarteritis Obliterans.—The endarteritis of syphilis was first accurately described by Heubner; it occurs either independently and by itself, or within a focus of syphilitic inflammation. The process begins with a cellular infiltration of the intima, which subsequently changes into connective tissue; the media remains more or less intact, or likewise changes into fibrous tissue. The thickening of the walls of the vessels in syphilis is not infrequently very considerable, and the lumen of the arteries may not only be narrowed, but even completely closed. The syphilitic inflammation also occurs in the intima of the veins. As Friedländer in particular has pointed out, there occurs not only in syphilis, but also in various other chronic inflammatory conditions, an obliterating endarteritis from proliferation of the endothelium of the larger arteries as well, which, when it affects an extremity, may threaten the integrity of the whole limb. Riedel observed gangrene of the leg following a circumscribed obliterating endarteritis of the femoral artery in a woman thirty-six years of age. Circumscribed or more diffuse infiltrations of the walls of the vessels are also produced by tubercular inflammation of these walls.

Congenital stenosis of the aorta (Morgani, Virchow, Fräntzel, etc.) is a matter of more consequence to the physician.

Sclerosis or Atheroma of the Vessels.—Atheroma of the arteries (arterio-sclerosis) is mainly a disease of old age, and is particularly apt to follow the habitual use of alcohol. It consists of thickenings of the intima, which occur in patches. The thickened parts, especially at the outset, are soft and jelly-like, or dense and fibrous, or more cartilaginous in character. The atheromatous patches often become calcified, or the tissue may break down and give rise to losses of substance (atheromatous ulceration). Atheroma may occur in all parts of the arterial system, from the valves of the aorta to the smallest arteries, and is sometimes developed to an extreme degree. Atheroma of the veins is more rare, and never of as high a grade. It is essentially an endarteritis which begins with inflammatory infiltration, and leads to a

new formation of connective tissue. This is followed by retrogressive changes (fatty degeneration, necrosis, calcification). As a result of arterio-sclerosis there occur a thickening, narrowing, or occlusion of the vessels, with secondary disturbances, and finally necrosis of the parts supplied by the affected vessel, as in senile gangrene (see Special Surgery). On the other hand, dilatation and rupture of the walls of the artery occur if the media also degenerates and loses its power of resistance.

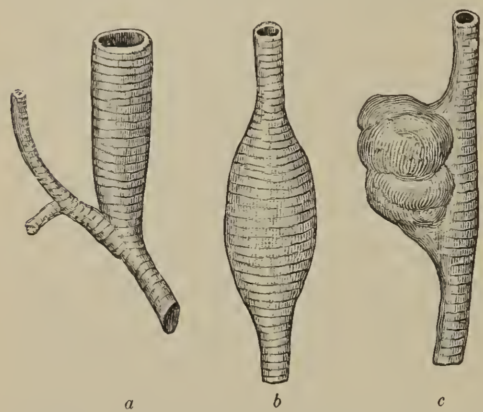


Fig. 322.—Various forms of aneurysms: *a*, cylindrical aneurysm; *b*, spindle-shaped; *c*, sacculated aneurysm.

Aneurysms.—By aneurysm is understood a dilatation of an artery filled with flowing blood. The dilatation is either limited to a certain portion of the artery (Fig. 322), or there is an expansion of a whole group of arterial branches and of capillaries with a simultaneous hypertrophy of their walls (Fig. 327). The latter form of aneurysm is called aneurysma racemosum or anastomoticum.

Aneurysms originate either from injuries or from gradual dilatation of the vessel as a result of disease of its wall, especially chronic endarteritis (atheromatous, syphilitic endarteritis), and periarteritis with secondary atrophy of the wall, particularly the media. Köhler saw a large axillary aneurysm which was caused by an echinococcus in the sheath of the artery. All primary and secondary diseases of the walls of the vessels by which the strength and elasticity of the walls are diminished may give rise to the formation of an aneurysm.

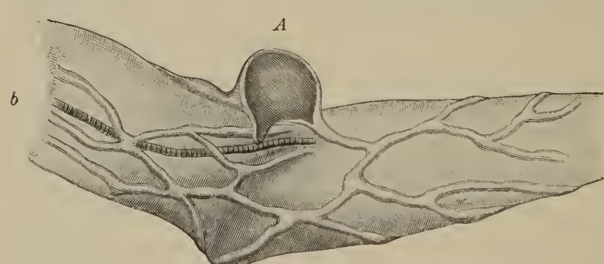


Fig. 323.—Aneurysma arterio-venosum (*A*) at the bend of the elbow, resulting from a venesection (Bell). The aneurysmal sack *A* is cut open (Froriep).

According to the views of Köster and Krafft, true aneurysms originate mainly from inflammatory processes in the media; but Recklinghausen, Manchot and others insist chiefly upon the presence of primary ruptures

of the media due to some traumatism, and a marked elevation of the blood pressure following, for example, some violent exertion; by these injurious influences the powers of resistance possessed by the arterial walls are lessened. An embolus lodging in a branch of an artery may also cause an aneurysm—for example, calcified endocarditic vegetations may bore their way into the wall of an artery, possibly in the brain, and erode it, causing it to give way and dilate—embolic aneurysms (Ponfick). Moreover, aneurysms may occasionally result from emboli of a suppurative or septic character with secondary necrosis of the wall of the vessel following endarteritis or periarteritis (Buday, etc.). All aneurysms developing from a gradual dilatation of all the coats of the vessel used to be called *true* aneurysms (aneurysma vera), in contradistinction to the traumatic aneurysms, which were designated as *false* (aneurysma spuria), from the fact that their walls do not consist of all three arterial coats. This distinction, as Cohnheim has correctly remarked, is an artificial one and incorrect. Traumatic aneurysms from a punctured injury, for example, are brought about by a gradual yielding of the thrombus in the wall of the vessel and of the surrounding cellular connective tissue, as a result of the intra-arterial pressure. A sack thus finally develops, the walls of which are made up of the outermost layers of the thrombus, the surrounding soft parts, and new-formed connective tissue. In the so-called true aneurysm the vessel dilates very gradually, as a result of chronic endarteritis, and according as the latter involves the entire circumference of the artery or only a portion of it, a cylindrical (aneurysma cylindricum) or spindle-shaped (aneurysma fusiforme) or sacculated (aneurysma sacciforme) aneurysm

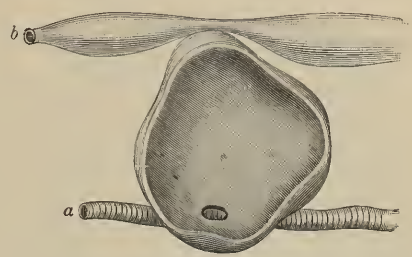


FIG. 324.—Aneurysma arterio-venosum: *a*, brachial artery; *b*, vena mediana. The sack of the aneurysm which communicates with the artery and vein is cut open (Dorsey).

FIG. 325.—Aneurysma arterio-venosum of the temporal artery and vein following an incised wound received twenty-five years before (Czerny).

develops (Fig. 322). Of course, there are many transitions between each of these different forms.

Occasionally an aneurysm communicates with an adjoining vein, as was formerly not uncommon after phlebotomy, in consequence of simultaneous injury to the brachial artery at the elbow. An aneurysm of this description Virchow calls an aneurysma arterio-venosum. This term is better than aneurysma varicosum or varix aneurysmaticus. The aneurysma arterio-venosum takes the form either of a circumscribed, sacculated tumour, as illustrated in Figs. 323 and 324, or, as a result of the communication between the artery and vein, there occur marked disturbances in the circulation, with pulsating dilatations of the distant branches of both artery and vein (Figs. 325, 326). If pressure is applied to the point of communication between the artery and vein, the pulsation in the dilated and tortuous vessels ceases and they collapse. In the extremities the arterio-venous aneurysm, as a result of the communication between the artery and vein, leads to circulatory disturbances throughout the entire limb, and to numerous small aneurysms and dilatations of the veins (varices), as in a case reported by Stromeyer and Krause (see Fig. 326).

A B

FIG. 326.—Aneurysma arterio-venosum of the left hand and forearm of a man forty-five years old, which had developed gradually after a bite on the hand received in his seventh year. Numerous sacculated aneurysms on the flexor side (*B*), and very marked varicose enlargement of the veins on the extensor side (*A*).

According to Bramann, of one hundred and fifty-nine cases of arterio-venous aneurysm, one hundred and eight were due to an injury, fifty-six following phlebotomy, twenty-nine gunshot wounds, five contusions which caused no internal wound, and nine were spontaneous. In only four instances was an arterio-venous aneurysm congenital. An arterio-venous aneurysm may develop spontaneously from a true aneurysm, which becomes gradually adherent to the vein. The latter becomes obliterated at the point of contact, or the aneurysm breaks into the open vein.

Aneurysma Racemosum, Anastomoticum, or Cirsoideum.—In aneurysma racemosum, or anastomoticum, or cirsoideum (arterial racemose angeioma, cirsoid angeioma), there is a cirsoid dilatation, tortuosity, and thickening of the artery throughout its entire distribution, forming a convoluted mass of enlarged arteries (Fig. 327). The racemose aneurysm occurs especially upon the scalp, is for the most part of congenital origin, and belongs more to the true tumours, and hence the term angeioma arteriale racemosum is more appropriate. Cirsoid aneurysm is rarely acquired, in which case it may result from some mechanical injury. A distinction used to be made between cirsoid aneurysm (varix arterialis) and the aneurysma anastomoticum (angeioma arterial racemosum, tumor vasculosus arterialis). The former was said to result more from a diffuse dilatation of the arterial branches, and eventually of the capillaries and veins; while the latter was said to be made up of newly formed dilated and lengthened arterial branches, resembling more closely a tumour. But both forms merge into one another to such an extent that it is impossible to make any distinction. An analogous tumour formation, the so-called plexiform neuroma (see Tumours of Nerves), occurs in the nerves.

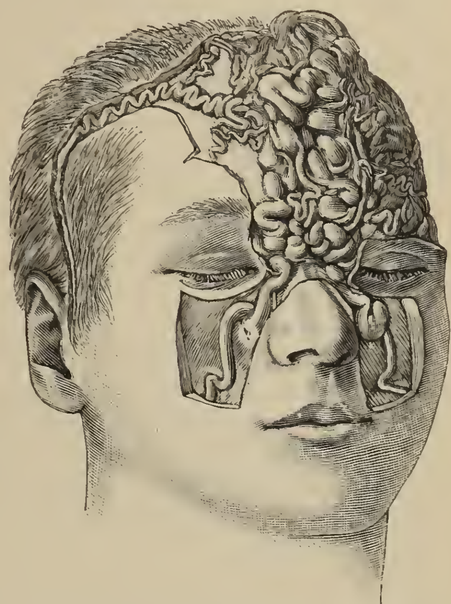


Fig. 327.—Angioma arteriale racemosum of the art. angularis and frontalis dext. and sinistr. of a man twenty years old (Bruns). Ligation of the right external carotid and the left common carotid. Death from cerebral embolus.

Aneurysma Dissecans.—The aneurysma dissecans is a particular kind of traumatic aneurysm resulting from rupture of the intima and media with preservation of the adventitia. It occurs especially in the aorta and small cerebral arteries. The blood escapes between the media and adventitia and lifts one from the other.

Occurrence of Aneurysms.—As regards the occurrence of aneurysms, they are most common in the thoracic aorta (the ascending and transverse portions), appearing next in order of frequency in the popliteal, carotid, subclavian, innominate, axillary artery, etc. According to Lüttich, out of one hundred and ninety-six cases, one hundred and sixty-

one were observed in men and only thirty-four in women. Aneurysms are comparatively common in England, particularly in the English army. The aneurysma cirsoides or anastomoticum is observed most frequently in the common iliac and on the scalp. Of aneurysms involving the small arteries, those in the brain, the lungs and the heart are especially important.

The Symptoms and Course of Aneurysms.—The most important symptoms of an aneurysm are brought about by the blood flowing into the sack, and consist in the presence of pulsation and a friction sound. If a hand is placed upon the tumour it will be felt to enlarge synchronously with the apex beat. By palpation and auscultation the friction sound can also be made out; it is caused by the blood rubbing against the inner wall of the sac. As regards diagnosis, a careful distinction must be made between the actual, true pulsation of an aneurysm and the communicated pulsation which results, for example, from a tumour or an abscess being lifted by an underlying large artery. If the pulsation is communicated, there is usually only a rise and fall in one direction, and the tumour does not expand equally in all directions, as is the case in the true pulsation of an aneurysm. But the pulsation of aneurysms is not always plain, it being very slight, for example, in those with thick walls. If the afferent artery of an aneurysm is compressed the pulsation and friction sound ceases. Mention should be made of the fact, which is of diagnostic importance, that very vascular sarcomata of bone, for instance, also pulsate.

When an aneurysm has once formed, the local dilatation of the lumen of the artery never returns to the normal again, but, on the contrary, it constantly increases, and in addition the wall of the vessel becomes steadily thinner, and finally the sac bursts, leading to fatal hæmorrhage, especially in aneurysms of the aorta, the brain and lungs, etc. As a result of the increasing enlargement of the sac, the surrounding parts are proportionately displaced and the bones are gradually more or less eroded—for example, the sternum, the vertebræ, and ribs, in aneurysms of the aorta. Pressure upon adjoining nerves gives rise to corresponding symptoms (pain, paralysis). The skin resists comparatively the longest time, but it also may be broken through, causing sudden death from hæmorrhage.

Spontaneous cure of an aneurysm by filling of the sack with a thrombus and by change of the latter into cicatricial tissue only occurs in the case of smaller aneurysms. The thrombi originate from the slowing of the current and the pathological changes in the wall of the aneurysm.

Extensive thrombi with many layers also develop in larger aneu-

rysms, but in these cases complete obliteration of the aneurysmal sac by cicatricial connective tissue does not take place. The thrombus formation sometimes increases to such an extent that the circulation is interrupted, and gangrene, possibly of the entire extremity, takes place. Occasionally the thrombi soften and break down, giving rise to embolic processes, or the thrombi may become calcified.

Diagnosis of Aneurysms.—From what has been said, it follows that the diagnosis of aneurysm is not difficult as long as we have to deal with cases which are accessible to careful examination. As regards diagnosis, the above-described true pulsation and the friction sound, as well as their disappearance after compression of the afferent artery, are the most important symptoms. Nevertheless good surgeons have made errors and taken aneurysms for abscesses, particularly in cases where there are manifestations of inflammation, swelling of the soft parts around the aneurysm, etc. If this mistake in diagnosis should occur, and the aneurysm be incised, resulting in a gush of blood, the incision should be immediately closed by placing the hand upon it, the afferent artery compressed, Esmarch's rubber tourniquet applied, and the main afferent artery immediately ligated in its continuity.

On the other hand, it may happen that an aneurysm is supposed to be present, while as a matter of fact we have to deal with a very vascular tumour. But from what has been said it should be an easy matter to make the correct diagnosis in such cases.

Prognosis of Aneurysms.—The prognosis of aneurysms varies greatly, according to their location. In general, the prognosis of aneurysms, as far as spontaneous cure is concerned, is unfavourable, as this termination is only possible in small arteries by the organisation of the thrombi, calcification, etc. In large aneurysms the sack constantly increases in size, and there is nothing to do but check the enlargement of the aneurysm by proper local treatment, and possibly to extirpate it.

Treatment of Aneurysms.—Mention may be made first of the operative treatment of aneurysms. The oldest method of operative treatment is that of Antyllus. It consists in splitting open and extirpating the sack after previously performing central and peripheral ligation of the main trunk of the artery and any branches which may be given off from the aneurysm. The aneurysm is exposed with the aid of Esmarch's artificial ischæmia and opened by incision. After removing the clot from the sack a probe is passed into the afferent and efferent ends of the artery, and both are closed by a ligature. After this all branches given off at any point from the wall of the sac must be tied. The aneurysm itself can then be extirpated, or, when this is too difficult, a portion of the sack may be left behind. The performance of this

operation may present great difficulties, in the first place, on account of the numerous branches which spring from the wall of the sack, and then because the central and peripheral ends of the artery on each side of the aneurysm may be so thickened that it may be very difficult to find and ligate them. Other methods of operative treatment for aneurysm consist in the ligation of the artery on the central or peripheral side of the aneurysm. The central ligation of the afferent arterial trunk is either performed close above the aneurysm (Anel), or at some distance from the latter at the so-called place of election, where the artery is easily accessible (Hunter). Ligation of the artery on the peripheral side of the aneurysm has been recommended particularly by Brasdor, Wardrop, and Desault. The formation of a thrombus in the sack, and thus its diminution in size by the development of cicatricial tissue, are said to be favoured by all these methods. Their success is uncertain, and, particularly after ligation of the afferent artery, even gangrene has been observed of varying extent in the region supplied by the artery. Ligation of the efferent artery is especially to be recommended when ligation of the afferent vessel is impossible or too difficult; thus in aneurysm of the innominate, for example, one would ligate the carotid and subclavian arteries. The best though at the same time the most difficult method is that of Antyllus. The next, as far as the certainty of its effect is concerned, is the ligation of the afferent arterial trunk close above the aneurysm, while ligation of the efferent artery close below the aneurysm is the most uncertain procedure. After ligation of the afferent artery at the place of election in Hunter's method, recurrence, as a general thing, easily takes place; nevertheless this method is of value for the reason that often in the neighbourhood of the aneurysm the artery is the seat of atheromatous disease, which makes ligation impossible.

Of the other methods of treatment we should mention, in the first place, digital and instrumental compression of the afferent artery, which is particularly adapted for aneurysms upon the extremities. This, also, is for the purpose of exciting a coagulation in the aneurysmal sac. The procedure is entirely devoid of danger, but it is often so painful that the patient cannot endure it long enough. Sometimes even gangrene of the skin may occur at the point where the pressure is applied. The procedure must as a general thing be continued for several days, and it is best for the compression to be kept the same for several hours (see Fig. 79). There must be several persons who can relieve one another in performing digital compression. Special pads, Esmarch's elastic bandage, or some other simple instrument such as a crutch or a broomstick, have been recommended for carrying out

instrumental compression. Forced flexion of the extremity has also been used in place of instruments (see Fig. 70). Probably the most advantageous way of carrying out this method is to apply an elastic bandage for about an hour and a half, enveloping the affected extremity from its periphery up to a point near the aneurysm; then an elastic tourniquet is applied around the extremity in the neighbourhood of the aneurysm on its proximal side, and after the lapse of about an hour and a half the bandage and tourniquet are removed, and digital or instrumental compression is employed for six to twelve hours. Pearce Gould recommends the administration of dry albuminous food and large doses of iodide of potassium before using the elastic compression, in order to increase the coagulability of the blood.

The other methods of treating aneurysm consist in exciting a coagulation of the blood in the aneurysmal sac by chemical means—as by the injection of ergotin, liq. ferri sesquichlorat., alcohol, etc.—or by foreign bodies (catgut, silver, steel or copper wire, horse-hair, laminaria), by acupuncture, and by electropuncture. I consider any treatment by injection dangerous, and, consequently, not to be recommended; especially after the injection of liq. ferri sesquichlorat., extensive clotting and speedy death from pulmonary and cerebral emboli have taken place. As regards the results obtained by the introduction of steel or copper wire (filipuncture) into large aneurysms, as Moore does in the case of aortic aneurysms, the recently published statistics of Verneuil are very unfavourable. Of thirty-four cases treated in this way, only two were cured, and thirty died comparatively soon after the operation. Phillippe obtained satisfactory results in dogs by the introduction of silver or copper wire, horse-hair, laminaria, etc., into the femoral or carotid artery. I have obtained very remarkable results in aortic aneurysms by means of galvano-puncture, the technique of which is described on page 79, and also in the Special Surgery.

The best treatment for the cases of cirsoid aneurysm and for arterio-venous aneurysm is extirpation, followed by careful arrest of all bleeding by ligation of the afferent and efferent vessels. In angeioma arteriale racemosum (cirsoid aneurysm) ligation of the main afferent artery is to be recommended; or ignipuncture may be performed with the galvano-cautery or with the fine point of the Paquelin instrument.

The treatment of ordinary aneurysms of course varies greatly with their location. In general it follows, from what has been said, that, whenever it is possible, compression should be tried first, alternating elastic bandaging with digital compression or compression by means of a stick. If this compression treatment is borne it can be continued for a long time; Billroth has kept it up for months. Not infrequently

compression proves successful after the lapse of months. If compression cannot be carried out or is not successful, an operation, when possible, should be undertaken, the best being that of Antyllus, or, if the latter cannot be used, Anel's, Hunter's, or Brosdor's operation should be performed in the manner described above.

Varices.—By varix is understood a dilatation of the wall of a vein (Fig. 328). This originates for the most part from mechanical interference with the return flow from the veins, and, consequently, occurs in local or general stasis, such as that due to the presence of tumours, particularly in the abdomen, or to pregnancy; or it is due to cardiac weakness, obstruction to the entrance of venous blood into the heart, etc. The greater the resistance, the greater will be the pressure under which the blood flows in the veins, and so much the sooner will the walls of the veins become stretched. The origin of varices is favoured by pathological changes in the walls of the veins and in the parts surrounding them. Occasionally an inherited disposition towards varices must be acknowledged. In predisposed individuals with flabby veins, comparatively slight causes may suffice to excite varices. Thus varices are produced in the lower extremities, for example, of individuals whose occupation compels them to stand a great deal.

Fig. 328.—Varicose ulcer of the leg (*a*), resulting from varicose veins.

Occurrence of Varices.—As regards the occurrence of varices, they are particularly apt to be found in parts of the body where the return flow of blood in the veins is rendered difficult, and consequently they are common in the lower extremities, at the anus (hæmorrhoids), in the scrotum, and in the spermatic cord (varicocele). Women suffer from varices more commonly than men, probably, in the main, as a result of pregnancy.

Symptoms of Varices.—One finds that especially the veins of the skin, and also the deeper veins of a larger or smaller area, are dilated evenly, or in the form of sacs or spindles, and are tortuous and lengthened (Fig. 326, *a*, and Fig. 328). Blue, sacculated, tortuous bands and convolutions are seen, varying in size, over which the skin is usually more or less thinned. Not infrequently, as a result of rupture of these var-

ices and the overlying skin, secondary hæmorrhages take place which, in the lower extremity, for instance, may cause death if not promptly arrested; under these conditions a spontaneous arrest does not easily occur. Sometimes periphlebitic inflammation and suppuration originate in the parts surrounding the varices, possibly in conjunction with an eczema or ulcer in the skin. Thrombi are also observed in varices as a result of retardation of the blood current in the dilated vessels, just as in aneurysmal sacks. They may or may not become organised, soften and break down, or become calcified. If they become calcified, the so-called vein stones or phleboliths result. When thrombi form, the dilated veins are plainly to be felt as firm, hard cords. Suppurative breaking down of the thrombi is observed, for example, in conjunction with an ulcer of the leg or eczema which has not been treated antiseptically. In this condition there is danger of the development of embolic processes and pyæmia from the carrying off of the suppurating clots into the general circulation. It is a matter of great practical importance that wherever varices exist there is a tendency towards inflammatory processes, with increased transudation and cellular infiltration. Hence it is clear why the development of vesicles and eczemas which break down and ulcerate are so common upon lower extremities where there are varices. Should a small injury be received, there is, for the same reasons, only a slight tendency towards repair, and an ulcer may readily result. The ulcers of the leg, which are so common, are usually observed in conjunction with varicosities, and so are correctly designated varicose ulcers of the leg (Fig. 328). In such cases there usually exists a pronounced inflammatory condition in the lower extremity, with hyperplasia, extensive œdema, and, in severe cases, a deforming of the foot and leg by an induration resembling elephantiasis.

The diagnosis and prognosis of varices may be inferred from what has just been said.

Treatment of Varices.—The treatment of varices varies with their cause and location. I must refer the reader to my Special Surgery for the detailed description of the treatment for varices of special localities—such as the leg, the rectum (hæmorrhoids), etc. Only the following brief statements can be given here: In the first place, varices can be cured by operative measures—such as extirpation after previously applying a catgut ligature, or by cauterisation with the galvano or Paquelin cautery, as in the case of hæmorrhoids. In severe cases Madelung has had good results from removal of the varices, in the lower extremity, for example, by the following method: By allowing the leg to hang down from the operating table the varices are caused to become promi-

nent; thin rubber tubing is tied around the upper third of the thigh, loosely enough not to compress the artery. The skin is divided by a longitudinal incision along the entire length of the varicose vein, and freed on both sides of the incision. The proximal portion of the vein —generally the saphenous—is secured by a double ligature, and the vein, with its ramifications, is removed from above downwards, without using the edge of the knife. The branches are seized by artery clamps and ligated. Percutaneous ligation (*Umstechung*) of the veins has also been recommended; a catgut ligature is carried on a curved needle under the vein and knotted on the skin, possibly over a drainage-tube. Even after extirpation of the varices recurrences are rather common. In extensive varices involving, for example, the subclavian vein and its branches, I can recommend a very simple and effective method, namely, ignipuncture—i. e., puncturing the varicose venous trunks with the galvano-cautery, or with the fine point of the Paquelin cautery. A protective dressing is ordinarily unnecessary, or, at the most, only for twenty-four hours. The puncture wounds dry and are covered by small scabs, which fall off after a time.

Ligation of the vena saphena magna is perhaps the best treatment for the varices of the leg which are so common (Trendelenburg). Trendelenburg has practised this simple operation for years with the best results. Its success is very surprising. Varicose ulcers of the leg also heal with remarkable rapidity.

The bloodless methods of treatment are, for the most part, only palliative in their nature. In the varices of the leg, for example, they consist mainly in the use of dressings which exert pressure, particularly laced stockings, or roller and elastic bandages. In general, Martin's cheap elastic bandage is preferable to the elastic stocking. If ulcers of the leg are present, they should be dusted with iodoform, dermatol, bismuth, or oxide of zinc, and over this dressing Martin's elastic bandage should be applied. With these bandages the patient can attend to his business. The bandages are taken off in the evening, thoroughly washed in water, and dried during the night. The greatest cleanliness is necessary in this method of treatment. Oftentimes the elastic bandage is not borne well, as it causes an eczema. In this case the rubber bandage should be left off and the eczema treated with some ointment and dusted with starch, or starch and zinc oxide (5 to 10 : 1), over which a cotton dressing is placed. In varices of the lower extremity, Landerer recommends compression of the internal saphenons vein by a truss consisting of a spring made in the shape of a parabola, and a pad filled with water; this is worn above or below the knee.

Finally, mention should be made of the injection of drugs into the

parts which surround the veins. Paul Vogt recommends cutaneous and subcutaneous injections of ergotin into the perivascular tissues. If this method is employed, as fresh solutions of ergotin as possible should be used (extract. secal. cornut., Wernich, 1 to 10 aq. destil.), to which it is a good plan to add a little carbolic acid (0·10) to prevent decomposition. It is wise not to permit the solution to stand for too long a time, but to renew it frequently. The solution is injected by a hypodermic syringe and the small punctured wound closed by iodoform collodion. If an abscess should result, it must be promptly incised. Injections of absolute alcohol, or of a few drops of concentrated carbolic acid, as in hæmorrhoids, are better than ergotin (Lange). Care must always be taken to avoid any direct injury to the vein and to make the injections only into the perivascular tissues.

§ 96. **The Diseases of the Lymphatic System.**—The acute and chronic inflammations of the lymph vessels and glands have been sufficiently described under the subjects of inflammation (§§ 56 to 58), acute lymphangitis and lymphadenitis (§ 68), tuberculosis, scrofula, syphilis, etc. We shall return to tumours of the lymph glands in the chapters on New Growths.

There only remains to be briefly discussed here lymphangeiectasiæ and lymph fistulæ with lymphorrhœa or lymphorrhagia.

Lymphangeiectasiæ.—Dilatation of the lymphatic vessels (lymphangeiectasis), from obstruction to the return flow of lymph, occurs under conditions similar to those which are present in dilatation of the veins. Lymphangeiectasiæ are not infrequently observed as a result of recurrent attacks of hyperæmia and inflammations of various kinds. The hyperplasia of the skin and subcutaneous tissue occurring in conjunction with frequently repeated inflammations, and which is called elephantiasis, is in the main a true lymphangeiectasis (see § 93). But, as a general thing, the return flow of lymph has so many channels through which it can pass that if stasis occurs compensation readily takes place, and for this reason an occlusion even of the thoracic duct may cause no serious trouble. Lymphangeiectasiæ are observed most commonly in the lacteal vessels of the mesentery. In rare cases, as a result of some traumatism, there occasionally develop circumscribed subcutaneous or interstitial collections of lymph—so-called lymph extravasations or lymph cysts similar to the hæmatomata derived from the blood-vessels.

As regards the symptoms which lymphangeiectasiæ give rise to, it should be briefly stated that in lymphangeiectasiæ of the skin the latter is filled with dilated, tortuous lymph vessels; the skin for this reason has a nodular appearance; it is covered with vesicles, and frequently,

as a result of hyperplasia of the tissues, comes to resemble elephantiasis. If the varices of the lymphatic network in the cutis are more pronounced, vesicles of different size develop. Not infrequently the varicose lymphatic vessels burst and give rise to a so-called lymph fistula. Gjeorgewic states that in fifty-five cases lymphorrhœa was observed twenty-two times in consequence of the spontaneous bursting of the varicose lymph vessels. The lymph usually exudes from one or more vesicles and sometimes from between the epithelial cells, as in one case which I saw, without an actual fistula being visible. Under these circumstances, the escape of lymph, the lymphorrhagia or lymphorrhœa may be very considerable. In one case of lymphangeiectasis of the labia majora in which a fistula developed, Nieden found that in four hours there was an escape of one and a half litre of a milky, slightly yellowish liquid containing fat and resembling chyle. The most serious lymphorrhagia is that which results from a rupture of the thoracic duct caused, for instance, by a traumatism or by an advanced degree of stasis, possibly from closure of its lumen by inflammation or a tumour in its neighbourhood. In such instances there is a great accumulation of lymph in the thoracic and abdominal cavities (chylous hydrothorax and chylous ascites), which will be described in the Special Surgery.

In the rare cases of circumscribed, subcutaneous, and interstitial collections of lymph which, as a result of a traumatism, for example, has escaped from the vessels, there develops a fluctuating, circumscribed swelling which at the outset grows rapidly and then usually remains stationary (lymph cysts). Should the extravasation of lymph continue, a lymph fistula may eventually form from a rupture of the skin.

The microscopic changes in lymphangeiectasiæ of the skin consist principally in the development of numerous irregularly shaped, complex cavities, lying in and close beneath the papillary layer of the cutis and, in fact, directly beneath the epidermis, which are lined with endothelium and communicate with the plexus of lymphatic vessels. Not infrequently lymphatic vessels with hypertrophic walls are found in the deepest layers of the cutis and subcutaneous cellular tissue.

Congenital Lymphangeiectasis.—The lymphangeiectasis is sometimes congenital, particularly in the tongue and lips (macroglossia, macrocheilia lymphangeiectatica), and also in the skin of the scrotum and labia pudendi.

Treatment of Lymphangeiectasis, Extravasations of Lymph (Lymph Cysts and Lymph Fistulæ).—The treatment of lymphangeiectasiæ is in general the same as for varicose veins, and often enough it is unsuccessful. In many cases cauterisation with the fine point of the

Paquelin or galvano-cautery renders excellent service. Successful extirpation may prove very difficult for the reason that the boundary between the diseased and healthy tissues is so hard to recognise. For lymph cysts compression should be tried, and if this fails, the sack should be laid open with or without cauterisation of its walls with a three- to five-per-cent. solution of carbolic acid. Lymph fistulæ have been cured by transverse division of the skin on the proximal side of the fistula. As regards the treatment of elephantiasis, injuries of the thoracic duct, and congenital lymphangeiectasiæ, I must refer the reader to my Special Surgery.

§ 97. **The Diseases of the Peripheral Nerves.**—We shall confine ourselves here only to the surgical aspects of diseases of the nerves—i. e., we shall only take up those which are capable of surgical treatment. We have already, in a previous chapter, discussed the most important diseases of the peripheral nerves. Degeneration and regeneration of nerves, following contusion or division of them, has been described in §§ 87 and 88, where the sequelæ of injuries to nerves, the paralyses, and the vasomotor and trophic disturbances have been discussed. Trismus and tetanus have been described under the subject of Infectious Diseases of Wounds (§ 73), and the symptoms of shock in consequence of injury to the sensory nerves in § 63. Inflammation of the peripheral nerves (neuritis) has been described in connection with injuries of nerves (§ 87), but the subject must be briefly reviewed at this place.

Neuritis.—Neuritis occurs in an acute and chronic form. The most common causes of neuritis are injuries of various kinds, cold, inflammations of neighbouring organs, and acute or chronic constitutional diseases, such as typhoid fever, the acute exanthemata, diphtheria, syphilis, leprosy, chronic alcoholism, etc. Often enough no definite cause for the neuritis can be demonstrated.

Anatomically, acute neuritis is characterised by redness and swelling and generally by a serous, or sero-fibrinous or purulent exudation between the bundles of nerve fibres. Microscopically, in addition to the above-mentioned manifestations of hyperæmia and inflammatory exudation there is found a commencing degeneration of the medullary sheath and axis cylinder of the nerve fibres, and a proliferation of the nuclei in the sheath of Schwann. Occasionally the nerve perishes more or less completely from suppuration or gangrene. In chronic neuritis there is partly a new formation of connective tissue, an induration and sclerosis of the nerve, and partly a degeneration of the nerve substance. In a man dying from alcoholism Eichhorst found a peculiar degenerative atrophy of the peripheral nerve fibres without con-

nective-tissue growth (neuritis fascians); there was also a corresponding atrophy of the muscles.

The symptoms of neuritis, as far as they concern the surgeon, have been described in § 87, under Injuries of Nerves. For further particulars we must refer the reader to the text books on the pathology of nerves. We have remarked before that neuritis gradually extends in the form of an ascending and descending neuritis and gives rise to corresponding disturbances. The *treatment* of neuritis depends upon the cause. In the main, the surgeon has to deal with injuries to nerves, of which the therapy has been given in § 88.

Multiple Neuritis.—Particular interest attaches to multiple neuritis, in the study of which Leyden has won great credit. He distinguishes the following forms: 1. The infectious form: paralyses following diphtheria, typhoid, and other infectious diseases, multiple neuritis in syphilis and tuberculosis. 2. The toxic form of multiple neuritis (lead, arsenic, and phosphorous paralysis, paralyses following CO and CS poisoning, ergotism, mercurial paralyses, alcoholic neuritis). 3. Spontaneous multiple neuritis following over-exertion, exposure to unusual cold, etc. 4. The atrophic (dyscrasic, cachectic) form following anæmia (pernicious anæmia), chlorosis, marasmus, cancerous cachexia, diabetes, and tuberculosis. 5. The sensory neuritis, pseudo-tabes, neuro-tabes peripherica: *a*, the sensory form of multiple neurites; *b*, the sensory neuritis of tabes. The pathogenesis, course, and treatment will be found in the text books on nervous diseases.

The relationship of the nervous system to diseases of the skin has been briefly stated in § 93, and we shall return to the subject of neuropathic bone and joint affections under Diseases of Joints. New growths of nerves are described under the subject of Tumours.

Traumatic Neurosis.—The so-called traumatic neurosis (railway spine) is the result of concussion of the brain and spinal cord following a fall, a railroad accident, a severe contusion, a blow, etc., and is of great clinical interest. Patients of this kind are often erroneously thought to be malingerers. We shall have to confine ourselves here to a very brief description of this disease. The course of the disease is somewhat as follows: Immediately after the accident there will often be symptoms of shock with marked depression. Then gradually a permanent or only temporary improvement begins. In the most unfavourable cases there will be observed later on disturbances of various kinds, particularly manifestations of irritation, and certain symptoms coming on in attacks, such as marked excitement, pains, over-sensitiveness of the special senses, impairment of voluntary movements, loss of memory, sometimes anæsthesia and sometimes hyperæsthesia, cramps, paralyses, etc. According to Förster and König, there is an objective symptom in traumatic neurosis consisting in a peculiar form of limita-

tion of the field of vision; a test object carried in a centripetal direction from the periphery to the centre of the field of vision is seen further peripherally than when the object is carried in the reverse direction—from the centre towards the periphery. Albin Hoffmann has rightly directed attention to the fact that traumatic neuroses have become much more common since accident insurance has been introduced, and that it occurs much less often as an actual disease in people who have previously been perfectly healthy than has hitherto been supposed. Accident insurance has directly increased malingering and traumatic hysteria. As a matter of fact, in the majority of cases, we have to deal with a psychosis or neurosis which is not based upon any anatomical changes in the central nervous system—in other words, a *hysteria*, as Strümpell and Charcot and his followers have rightly emphasised. But in a small number of severe cases there are actually progressive anatomical changes in the central nervous system which result from the concussion it has sustained. The prognosis of a pronounced traumatic neurosis is often very unfavourable, as chronic ill health may easily result. The treatment of the traumatic neuroses is a subject that belongs to neuro-pathology.

Neuralgia.—By neuralgia (from *νεῦρον* and *ἄλγος*) is understood a disease of the sensory nerves the chief symptom of which is pain. The pain is usually localised in a particular nerve, is of considerable intensity, and is generally intermittent or remittent. The neuralgias belong to the most common neuroses, and their causes are very numerous. There often exists a pronounced neuropathic disposition. Of the most common causes there may be mentioned in particular traumatic and mechanical influences, inflammations, compression, disturbances of circulation, also taking cold, infections like syphilis, malaria, poisoning by lead or mercury, and finally diseases of the central nervous system, etc. Gussenbauer has directed attention to the fact that habitual constipation is a comparatively frequent cause of trigeminal neuralgia, and I can confirm his experiences throughout. The pain usually comes on in attacks of varying intensity and duration. The course of the neuralgias is sometimes acute—a few days or a week—and sometimes chronic, extending over weeks, months, or years. A large number of the cases are incurable, and last throughout the rest of life. Neuralgias of the trigeminus, the sciatic and intercostal nerves are particularly common.

Treatment of Neuralgia.—The treatment of neuralgia requires first of all that the cause of the disease should be determined by a careful examination of the patient. By overcoming habitual constipation, anæmia, affections of the genital apparatus, especially in women, etc.,

surprising cures of long-standing reflex neuralgias have often been brought about.

The forms of treatment of neuralgia itself are very numerous, and include particularly the use of electricity, narcotics (morphine, atropine), especially in the form of subcutaneous injections, and various drugs, such as chloroform, ether, nitrite of amyl, and chloral hydrate; also the internal administration of arsenic, quinine, preparations of iron, bromide of potassium, iodide of potassium, strychnine, and surgical measures, particularly massage, nerve-stretching, nerve division (neurotomy), resection of a greater or less portion of a nerve (neurectomy), or extraction of the affected nerve trunk (Thiersch). Electricity is sometimes very effective, especially the galvanic current. In addition to the above-mentioned remedies, counter-irritation of the skin, powerful electrical stimulation, vesicants, the red-hot iron, etc., may be tried. In suitable cases there is great advantage in sea-bathing or in hot springs (Gastein, Schlangenbad, Pfäffers, Ragatz, Wildbad, Wiesbaden, Teplitz, Leuk, etc.), or in cold-water cures, grape cures, and particularly in mountain life with proper exercise. Massage is often very successful.

Neurectomy and Extraction of the Nerves.—The surgical or operative treatment of neuralgia by neurectomy or extraction of the diseased nerves only succeeds when the neuralgia is dependent upon a peripheral cause. But even in such cases recurrences often occur, although no reunion of the divided nerve has followed the operation. After extraction of the affected nerve, the collateral branches which have been left intact may give rise to a recurrence, and permanent cures after neurectomy are rare, as is shown by the recent statistics of Conrad taken from the clinic at Bonn. Operations were performed ten to fifteen times for facial neuralgia, for example, without a single permanent cure.

The technique of neurectomy and of extraction of the diseased nerves is described in the Special Surgery.

Nerve-stretching.—Nerve-stretching was first practised by Billroth and Nussbaum for chronic affections of the nerves, for epileptiform attacks, and for neuralgias, and has been employed with greatly varying success for sciatica, tabes, and other nervous diseases. The operation is performed by exposing and isolating the sciatic nerve, for instance, above the poplitcal space or higher up at the lower border of the glutæus maximus, and having grasped the nerve with the thumb and index-finger, it is stretched by a vigorous pull until it has become plainly lengthened. Nerve-stretching is only indicated in diseases of the peripheral nerves and not in affections of the central nervous

system. The effects of nerve-stretching are probably due to the production of an acute traumatic inflammation of the parts surrounding the exposed nerve, by which pathological conditions, such as degenerative processes, adhesions, etc., are improved. In cases of spasm of the facial nerve, and in severe cases of long-standing sciatica, I have practised nerve-stretching with good results.

Bloodless Stretching of the Sciatic.—For neuralgia of the sciatic nerve (sciatica) it is an excellent plan to employ bloodless stretching by extreme flexion of the straightened leg at the hip joint, combined with massage.

§ 98. **The Diseases of Muscles, Tendons, and Tendon Sheaths.**—Inflammation of muscles (myositis) originates most commonly from traumatisms, and secondarily from inflammation of the immediately adjoining parts as a result of disturbances of circulation, or in the course of infectious bacterial diseases (pyæmia, typhoid, glanders, etc.). The inflammatory process in the muscle is localised principally in the connective tissue lying between the primitive muscular fasciculi, in the perimysium internum, and causes secondary changes in the contractile muscular substance. In other cases the latter is primarily the seat, for instance, of atrophy and degeneration, and the changes in the intermuscular connective tissue are secondary.

Inflammatory Muscular Contracture.—Apart from the local inflammatory disturbances occurring in the various forms of myositis, contracture of the inflamed muscle is one of the most important manifestations. We shall discuss the subject of contractures more fully later on, and we shall see that they may originate from many causes, such as disease of the muscles, nerves, bones, and joints, or from cicatricial shrinkage. As regards inflammatory contractures, it may be briefly noted that every inflamed muscle loses its elasticity and extensibility to a greater or less extent, and that the patient instinctively avoids the pain due to the stretching of the muscle by shortening, or, in other words, contracting it. The inflammatory muscular contracture originates in this way, and may become very severe. In this class of inflammatory, purely myogenic contractures, belong also the so-called ischæmic muscular paralyses and muscular contractures, such as those which follow the too tight application of dressings, and which were first accurately described by Volkmann, and then by Leser. The ischæmic contractures and paralyses are produced by cutting off the arterial supply, especially of the hand and forearm, for too long a time by tight dressings, Esmarch's constriction, ligation and injuries of the larger vessels, as well as by the prolonged action of excessive cold. The contractile muscular substance coagulates, undergoes waxy degeneration, and is

subsequently absorbed (Heidelberg, Kraske). There is regularly found a noticeable diminution or absence of muscular nuclei (Molitor), and the nuclei of the smallest capillaries also share in these changes. In such cases the muscle is no longer capable of regeneration ; it dies. It is really a *rigor mortis* of the muscle, though the nerves retain their power of conduction. If the ischæmia does not last so long a time, only a part of the muscular fibres undergo degeneration, and the rest persist and retain their power of regeneration. The ischæmic contracture is marked by a high grade of resistance to extension into a straight position. The prognosis of the ischæmic paralysis and contracture depends upon the number of muscular fibres which have perished, the worst cases being incurable, and even the milder ones requiring vigorous treatment by massage, electricity, and passive motion. An attempt should always be made to stretch the shortened and stiffened muscles, if necessary, under chloroform narcosis.

Myositis Serosa and Sero-fibrinosa.—The slight degrees of inflammation of muscle—the *myositis serosa* and *sero-fibrinosa*—which may follow contusions, for example, are characterised anatomically by a saturation of the perimysium with serum and by cellular infiltration, particularly between the muscle fibres. The latter remain intact, or, according to the nature of the excitant of the inflammation, they undergo a cloudy swelling, fatty degeneration, and coagulation necrosis. The defect in the contractile muscular fibres is more or less restored by proliferation of the muscular corpuscles (see page 468, Regeneration of Muscle). If a severer grade of inflammation, such as a *purulent* myositis, occurs, the muscular fibres are destroyed *en masse* by degenerative processes; they break down and undergo suppuration and putrefaction. Myositis purulenta may be acute or chronic, taking the form of muscular abscesses or of a diffuse suppuration or putrefaction, as described in the chapter on Cellulitis. The suppurative and gangrenous inflammations of muscle are always due to bacterial infection, and are observed in conjunction with infected, septic wounds of various kinds, occurring in the course of pyæmia, erysipelas, typhoid, glanders, endocarditis, etc. Multiple abscesses in different muscles often occur in great numbers. The muscular abscess occurring in the course of tuberculosis, the so-called cold abscess, such as the tubercular abscess or suppuration of the psoas muscle following tubercular disease of the vertebræ, runs an exceedingly chronic course unless it receives energetic surgical treatment. Diffuse suppurative and gangrenous changes in muscle are particularly apt to make their appearance in conjunction with a compound fracture which has not been treated aseptically.

Wherever muscular tissue has been destroyed by suppuration or gangrene there will remain, after healing has been accomplished, a permanent defect which is repaired by connective tissue, since, as we remarked on page 468, contractile muscular substance possesses but slight powers of repair. Corresponding to the size of the defect, the connective-tissue adhesions and the increasing cicatricial contraction, disturbances in the functions of the muscles will subsequently develop in the form of contractures, which may render the affected extremity completely useless.

Myositis Fibrosa.—Chronic inflammations of muscle take the form of a *myositis fibrosa.* In this we have to deal, in the main, with a growth of firm connective tissue between the muscular fasciculi and a proportionate atrophy of the latter. This fibrous myositis, or sclerosis of a muscle, occurs either diffusely, changing the entire muscle into tough connective-tissue masses, or it is confined to certain spots. In this category belongs the myositis fibrosa of the biceps or sterno-mastoid muscles, for example, occurring in the course of syphilis, or after paralyses, or primary muscular atrophies due to different causes.

Myositis Ossificans.—Special interest attaches to *myositis ossificans.* The development of bone in muscle is observed under various patho-

Fig. 329.—Ossified M. brachialis internus; the tendon is not ossified (Blasius and Volkmann).

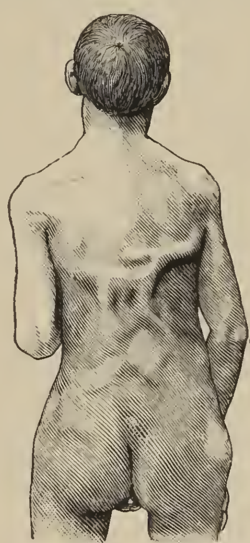


Fig. 330.—Myositis ossificans multiplex progressiva of the muscles of the back in a man twenty-four years old (Helfreich).

logical conditions; for example, in conjunction with callus formation after a fracture. Bone occasionally forms in muscle as a result of

some frequently repeated traumatism, such as the kick of a gun, which may give rise to the development of bone in the biceps and pectoralis muscles (the so-called exercise bones). Riding may lead to bony formation in the adductors of the thigh (riders' bone). In rare instances osteomata, not connected with any bone, have been observed, for which no cause could be discovered. Fig. 329 represents a case in which the brachialis anticus was completely changed into bone. Düms observed, in connection with the formation of bone in the deltoid muscle, a reflex neurosis, consisting of tremor and pains in the entire arm down to the finger tips, which only occurred when the gun pressed upon the exercise bone (osteoma), and disappeared completely after its extirpation.

Myositis Ossificans Multiplex Progressiva.—This is a very peculiar affection which generally begins during childhood. A great number of muscles gradually change into bone, causing the condition of the patient to become extremely deplorable. After the reception of some slight traumatism, or without any apparent reason, painful, doughy swellings develop in the muscles and intermuscular connective tissue, and in a few days they disappear. The muscle, at the point where it has been attacked, then feels hard, and true bone gradually develops. Nodular, branching masses of bone develop, especially in the muscles of the back and neck (Fig. 330). The jaws may be firmly held together by ossification of the masseters, and the movements of the vertebræ and the different joints may become lost in consequence of the ossification of the muscles, tendons, and ligaments. These pitiable individuals finally die in misery from motor disturbances, or from interference with respiration and nutrition. The bone always develops in the connective tissue in a manner analogous to the periosteal formation of bone, and the muscular fibres are passive throughout the entire process.

The nature of this very remarkable disease is still but little understood. There is evidently a pronounced tendency to the formation of bone in the connective tissue of the muscles, fascia, tendons, and ligaments, as though periosteum had strayed into these tissues. The affection is, in all probability, a congenital anomaly of development, especially as in some cases malformations of the extremities have been present at the same time (micro-dactylia, congenital anchylosis in the joints of the big toes and of the thumbs). In some of the cases the process should be looked upon as a formation of multiple exostoses, with secondary muscular ossification. At all events, I cannot regard the nature of the disease as inflammatory, but rather as one of tumour formation.

The treatment of the severe cases of myositis ossificans offers no hope, but the milder cases may derive some benefit from iodide of potassium and inunctions of ungt. hydrarg. ciner. Whenever possible, operative measures should be undertaken—i. e., the ossified muscle should be extirpated, and, if it be connected with the periosteum and bone, the periosteum and cortical layer of bone should also be removed.

The treatment of the above-mentioned acute and chronic inflammations of muscle is conducted upon the lines which have been laid down for the treatment of inflammation and suppuration.

Calcification of the Muscles has no clinical importance. It occurs in the neighbourhood of inspissated abscesses and in indurated inflammatory swellings. Extensive calcification, such as Meyer observed in the muscles of the leg, is exceedingly rare.

Muscular Rheumatism.—Acute and chronic muscular rheumatism depend upon inflammatory changes which are quite transitory in their nature. There are usually no gross anatomical changes in a chronic muscular rheumatism which has lasted for years; but the acute form is, for the most part, a serous or sero-fibrinous myositis. We still know but very little about the nature of muscular rheumatism. The manifestations of acute muscular rheumatism are very much like those exhibited after subjecting the muscles to some traumatism. It occurs especially as lumbago and as rheumatism of the sterno-mastoid muscle (rheumatic torticollis). In addition to the rheumatic forms of lumbago there is also a traumatic form which follows, for example, forced forward flexion of the back. The rheumatic affection of the sterno-mastoid is usually accompanied by a marked contraction of the muscle, causing the head to be inclined towards the affected side (rheumatic *caput obstipum*).

Chronic muscular rheumatism is characterised by shooting, tearing, generally vague pains in the substance of the muscle, which are usually excited or increased by bad weather. In the subsequent course of a given muscular rheumatism it often turns out that some constitutional disease is present, such as syphilis, tuberculosis, carcinoma, etc. The best treatment for the true acute and chronic muscular rheumatism consists, according to my experience, in the use of massage, in the diligent exercise of the affected muscles, and also in cold-water cures and the use of warm springs (Teplitz, Wiesbaden, Rehme, Gastein, etc.). Electricity is also serviceable; but massage, skilfully administered and combined with muscular exercise, is the best therapeutic measure.

Tuberculosis of Muscles.—Tuberculosis of the muscles is most commonly secondary to tubercular disease of the surrounding parts, or it

follows deposition of the tubercle bacilli by the circulation, such as occurs in general miliary tuberculosis (see § 83, Tuberculosis).

Syphilis of Muscles.—Syphilis may become localised in muscles, occurring sometimes in a diffuse form, as myositis fibrosa, and sometimes circumscribed, as a gumma tumour, especially in the sterno-mastoid muscle. Braman is right in calling attention to the fact that many of the so-called rheumatic indurations of muscle are due to syphilis.

Muscular Atrophy.—*Atrophy* of the muscles is observed in various pathological conditions. Atrophy and degeneration may follow inactivity of the muscles (atrophy of disuse), such as, for example, occurs temporarily after the application of immobilising dressings for joint disease; or it may be due to disease of the central or peripheral nervous system (neuropathic atrophies), or to the above-mentioned inflammatory processes, traumatisms, etc. The muscular atrophy accompanying joint affections is sometimes not the result of disuse, but is caused by the local disease near by—that is, by an involvement of the muscles in the diseased process going on in the joint, as is the case particularly in acute articular rheumatism (Strümpell). According to Paget, Hoffa, and others, the muscular atrophy accompanying joint disease is essentially reflex in its nature—i. e., the terminations of the nerves in the joints are irritated by the inflammation going on there. This irritation is carried centripetally to the ganglion cells in the anterior horns of the grey matter in the spinal cord—i. e., to the spinal centres of the nerves governing the nutrition of the atrophying muscles—and excites in them certain changes which produce the muscular atrophy. The reflex atrophy does not take place in dogs, for example, when the knee-joint is inflamed, if the posterior roots of the third, fourth, and fifth lumbar and first sacral nerves have been divided (Hoffa, and others).

Anatomically, we distinguish the following forms of muscular atrophy:

1, Simple atrophy of the muscular fibres; 2, atrophy, with an interstitial growth of fat cells (lipomatosis of the muscles); and, 3, degenerative atrophy.

In simple muscular atrophy following local or constitutional disturbances of nutrition, the muscular fibres decrease in size and number, and no other anatomical changes can be found. Atrophy of the muscular fibres, with a growth of adipose and connective tissue between the muscular fibres, is frequently observed. Generally the growth of the fat and connective-tissue cells is secondary to primary atrophy and degeneration of the muscles. Occasionally the development of fatty

tissue in the muscle is so extensive that the latter increases in size. This is the case in atrophia musculorum lipomatosa.

Pseudo-Hypertrophica or Dystrophia Muscularis Progressiva (Erb).—This disease occurs almost exclusively in children, particularly boys, and consists in a gradually developing simple atrophy of the muscles, with a secondary interstitial growth of fat cells, which may become so pronounced that many muscles—among others those in the calf of the leg—become considerably increased in size. In addition to these abnormally hypertrophied muscles there are others which are greatly emaciated. The atrophy spreads, and involves the greater part of the muscular system; the paralysis of the muscles steadily increases, and the patients become constantly more helpless. Death usually occurs within five to ten to fifteen years from marasmus or from paralysis of the muscles of respiration. The pseudo-hypertrophy is a primary disease of the muscles, and is probably due to a congenital change in the muscular tissue, which, at the period when development takes place, leads to a growth of fat in the perimysium internum and to atrophy of the muscular fibres.

Fatty Degeneration.—The fatty degeneration of the muscular fibres belongs to the degenerative atrophies of muscle. In this the primitive muscular fasciculi change into fat as a result of inflammatory processes, or inactivity due to paralysis, or of trophic disturbances due to a degeneration of the anterior roots of the spinal nerves; or it may occur in connection with an anchylosis or one of the acute infectious diseases (typhoid fever, diphtheria), or may follow phosphorus poisoning, etc. The so-called progressive muscular atrophy belongs to this group. The form of progressive muscular atrophy described by Duchenne and Aran is produced by spinal disturbances, while other forms are dependent upon multiple disease of nerves, or have the nature of primary muscular affections. To this latter class of cases belongs juvenile muscular atrophy (Erb), which runs its course sometimes with and sometimes without lipomatosis. The atrophy of the muscles is, for the most part, primary, and as it increases paralysis gradually develops. The disease begins in a particular group of muscles, often, for example, in the hand or the ball of the thumb. The atrophy then spreads intermittently, and in the severest cases gradually attacks the majority of the muscles. Progressive muscular atrophy belongs to the domain of nervous diseases, and consequently we cannot take it up more fully here.

Waxy Degeneration occurs especially in typhoid and puerperal fevers as a result of contusions, in tetanus, and after the muscles have become thoroughly tired out by electrical stimulation (Roth). We

have to deal in this condition with a death and a coagulation of the contractile muscular substance into a translucent hyaline mass.

Amyloid Degeneration of the Muscles.—Amyloid degeneration, which may involve the muscles of the tongue and larynx as a result of inflammatory processes, is a very rare disease of muscle. According to Ziegler, amyloid degeneration affects the perimysium internum and sarcolemma, causing them to become thickened and present a homogeneous appearance, while the contractile substance disappears.

Hypertrophy.—*Muscular hypertrophy* has no practical interest; it is partly acquired and partly congenital.

Muscular Defects.—Congenital muscular defects, which may occur in the pectoralis major and minor and in other muscles, should also be mentioned.

Tumours of muscles are discussed under the subject of tumours. Of animal parasites which occur in muscles there are the trichina, the cysticercus cellulosæ, and the echinococcus (see Special Surgery). Marguet states that the echinococcus is found most frequently in the adductors of the thigh, in the glutæi, the quadratus femoris, biceps of the arm, the pectorales, the trapezius, deltoid, and muscles of the back and abdomen. They form fluctuating tumours which should be removed by extirpation or by incision, followed by scraping them out. Actinomycosis of muscles is described in § 86.

Inflammations of the Tendons and Tendon Sheaths may occur, in the first place, as a tenosynovitis acuta sicca (tenalgia crepitans), a form which corresponds to dry pleurisy (pleuritis sicca). This is characterised by a deposition of fibrin upon the inner surface of the tendon sheath and upon the surface of the tendon. As a result of this roughening, when the tendon is moved a soft crepitation or a grazing or creaking sound is communicated to the hand held over the inflamed region. This form of tenosynovitis affects most commonly the extensor tendons of the forearm in individuals who work at heavy manual labour; it may also occur in the tendons of the leg (the tibiales and Achilles tendons) after a long march, for example.

The treatment of tenalgia crepitans consists in painting the parts with tincture of iodine, in immobilising them with proper dressings (splints, etc.) and applying moderate pressure with cotton, and later employing massage and passive motion. I use massage as soon as possible. Recovery usually takes place in one to two to three weeks.

Tenosynovitis Acuta Purulenta.—Suppurative inflammation of the tendons and tendon sheaths (tenosynovitis acuta purulenta) is most commonly the result of some injury which has not been treated antiseptically, and of a suppurative process in the neighbourhood. Suppu-

rative inflammation of the tendons and tendon sheaths has been described under the subject of Cellulitis, in § 70, and consequently will be only briefly mentioned here. In the fingers, especially, the so-called paronychia or whitlow easily spreads to the tendon sheaths (panaritium tendinosum). Suppurative tenosynovitis is characterised by a collection of pus between the tendon and its sheath, and by a cellular infiltration of the intrafascicular connective tissue. The milder cases, which are treated by incision and antiseptic dressings, terminate in a *restitutio ad integrum ;* in others, an adhesion of the tendon to the tendon sheath or a necrosis of the tendon take place.

The *treatment* of suppurative tenosynovitis consists in making an incision at the earliest possible moment, followed by drainage and antiseptic dressings (bichloride of mercury, iodoform). It is a very important matter to place the diseased limb in a suitably elevated position. If the hand, for example, is involved, it should be suspended vertically by means of suspension splints (see Fig. 177). If the suppuration of the tendon sheaths is extensive, the same treatment should be employed as was described for cellulitis in § 70. The cataplasms which used to be employed have been given up entirely, and the ice treatment is also not very effective. Whenever it is possible, suppuration should always be anticipated, and its extension should be prevented. If necrosis of the tendon occurs, care should be taken to keep the affected portion of the limb in the position in which it will be the most useful afterwards. The treatment of defects in tendons is discussed on page 467.

Tuberculosis of the Tendon Sheaths.—Tubercular tenosynovitis occurs both as a primary disease and secondary to tuberculosis in the neighbourhood. Primary tuberculosis of the tendon sheaths is not so rare as used to be believed ; it develops occasionally from some traumatism (contusion, sprain). Tubercular tenosynovitis is characterised by the formation of miliary tubercles, greyish-red, gelatinous granulation tissue, and in the later stages by the formation of caseous or suppurating masses which are distributed along the tendon. In the benign cases of tuberculosis of the tendon sheaths, Goldmann states that the process is a fibrinoid degeneration, and that cheesy degeneration does not occur. The fibrinoid degeneration often leads to the formation of rice bodies—that is, the degenerated fibrous and villous growths break loose and become free corpuscles (corpuscula oryzoidea), which are like grains of rice ; in this way the so-called rice-body hygroma develops (see page 559).

The *treatment* of tubercular tenosynovitis consists in carefully removing the tubercular deposit with the scissors, forceps, and sharp spoon. I have obtained excellent results, and even entire cures, in

primary tuberculosis of tendon sheaths. Care must always be taken that every bit of the diseased tissue is removed. Iodoform injections which are well worth recommending are discussed on page 420. Losses of substance in tendons can be remedied as described on page 467.

Hydrops Tenovaginalis (*Hygroma of the Tendon Sheaths*).—By hygroma or hydrops tenovaginalis is understood a cystic formation which occurs especially in the tendon sheaths of the hand, particularly in the palm, where it affects the flexor tendons beneath the anterior annular ligament, also in the fingers and on the dorsum of the hand. It consists essentially of an abnormal increase in the secretion of the tendon sheath. Some hygromata are, as we have said, tubercular in their origin. To avoid repetition, we shall discuss hygroma of the tendon sheath, together with hygroma of bursæ, in § 99.

Tumours of Tendon Sheaths.—We shall return to tumours of the tendon sheaths under the subject of tumours. Fibromata, fibrosarcomata, sarcomata and lipomata are liable to occur in this situation. The latter kind of tumour occasionally forms diffuse growths (lipoma arborescens) which are sometimes symmetrical.

Myotomy and Tenotomy.—Brief mention should here be made of the subcutaneous division of muscles and tendons—subcutaneous myotomy and tenotomy—an operation which is often practised for contractures. The operation is performed in the following manner: The tenotome, a pointed, slightly curved knife (see Fig. 45, page 66), is introduced with antiseptic precautions, and the muscle or tendon—it may be the tendo-Achillis or contracted fascia — is cut through subcutaneously. The small punctured wound is covered with an antiseptic dressing which exerts pressure. The defect which forms between the retracted ends of the tendon is then filled in by newly developed connective tissue. The missing portion of tendon becomes entirely regenerated, and the muscle suffers no loss of function. The intervening portion of tendon is developed from the cellular sheath, that wide-meshed connective tissue which partly envelops the tendon and is partly inserted upon it by means of bands (vincula tendinum). The technique and indications for myotomy and tenotomy in particular portions of the body is discussed in the Special Surgery.

§ 99. **The Diseases of the Bursæ.**—The bursæ mucosæ are more or less sharply defined connective-tissue sacks having a smooth inner surface which is covered with endothelium, and, like the joints, secretes synovia.

Origin and Occurrence of Bursæ.—Bursæ, as a rule, develop in places where the skin, fascia, muscles, etc., are subjected to continual pressure and friction, particularly over bony prominences. This explains why the num-

ber of bursæ is not constant, and why bursæ form in portions of the body other than where they normally occur (so-called accidental or supernumerary bursæ). One may thus develop upon the first metatarsal bone in hallux valgus, over the spinous processes in kyphosis of the vertebræ, upon the sternum of shoemakers, etc. Young children lack a large number of bursæ which subsequently develop as the parts become subjected to increased use. Bursæ originate from the soft connective tissue which lies between two layers of tissue, and which becomes more and more wide-meshed. The space in the tissues is at the outset irregular and contains atrophied connective-tissue fibres, but it develops by degrees into a complete sack with smooth walls and endothelium like any other connective-tissue space. The number of the more or less constant bursæ is very great. Gruber found eighteen in the parts around the knee joint and eleven bursæ musculares at the elbow joint, in addition to the bursa anconea epitrochlearis and epicondylica. Velpeau found fourteen bursæ on the dorsum of the hand, etc.

Acute Inflammation of a Bursa.—The acute inflammation of a bursa (acute hygroma, bursitis acuta) is either serous, sero-fibrinous, or purulent. All cases of acute bursitis give rise, in consequence of the increased secretion, to a more or less prominent fluctuating tumour. The purulent inflammation occasionally takes on a phlegmonous character, causing the pus to burrow into the neighbouring cellular tissue or into joints, etc. The bursa most commonly inflamed is the bursa præpatellaris (see Special Surgery).

Chronic Inflammation of Bursæ (Hygroma).—The most common form of the *chronic* inflammation of bursæ is the hydrops or hygroma. In the majority of instances it occurs as a painless fluctuating tumour, without change in the cutaneous covering. Its contents consist of a thick, mucoid liquid. The shape of the tumour corresponds to the degree of extension of the bursa. The hygroma præpatellare is the most common of all hygromata of bursæ (see Special Surgery). Should a communication exist between the hygroma and a joint, a corresponding serous effusion will be found in the latter. Hygromata sometimes develop in connective tissue from fibrinous exudation without the previous formation of a bursa.

In other cases of hygroma the walls become thickened to a greater or less extent (fibrous degeneration), particularly if the disease has existed a long time, or a villous growth takes place in the bursa and the villi may break loose and form rice bodies (corpuscula oryzoidea). Occasionally there will be so many free bodies in the hygroma that the latter feels like a bag filled with shot (ganglion crepitans, hygroma proliferum). The free bodies, according to Meckel and Volkmann, originate partly from the breaking loose of the villous, fibrillar growths which become enlarged by infiltration and deposits of the albuminous and fibrinous matter contained in the synovia, and partly from the

precipitation or coagulation of the thickened contents of the hygroma. Schuchardt states that the rice bodies are formed mainly by the breaking loose of the degenerated portions of tissue from the walls of the bursa, tendon, or tendon sheath after they have undergone coagulation necrosis (Weigert) or a fibrinous degeneration (Neumann). Free bodies may also be formed by growths of cartilage which break loose from the hygroma. The shape of the body is round, elongated, facetted, or like a pear, cucumber, or melon. Their number varies greatly, often reaching many hundreds.

The hygroma of the tendon sheaths mentioned on page 558 presents practically the same manifestations as that of the bursæ.

A hygroma originates almost always from mechanical causes, especially from prolonged mechanical irritation, from contusions, sprains, etc. Volkmann believes that the rare cases of multiple hygromata are occasionally due to rheumatic causes. Syphilis not infrequently gives rise to hygromata, particularly of the tendon sheaths, in addition to corresponding serous effusions into the joints. As we remarked on page 557, these rice-body hygromata are sometimes tubercular in their nature, running a comparatively benign course, and exhibiting a fibrinoid degeneration of the tubercular tissue, but not a cheesy degeneration (Goldmann).

Part of the proliferating hygromata must be looked upon as tumours, some of them being benign, endothelial growths (Morisani), and others malignant, sarcomatous tumours (Mikulicz).

The best treatment for hygromata consists in puncture followed by antiseptic irrigation with a 1-to-1,000 solution of bichloride of mercury or a three-per-cent. solution of carbolic acid; or, better still, an incision should be made and the hygroma extirpated with antiseptic precautions as completely as possible. The procedures which were practised in the days before antisepsis (application of the tincture of iodine, pressure, etc.) are uncertain (see Special Surgery).

The treatment of acute inflammation of bursæ is conducted according to general rules. Painting the part with iodine, pressure, and massage will often suffice for the milder serous effusions. If there is a violent inflammation or suppuration, aseptic incision is the only proper procedure. It will be sufficient to puncture large, purely serous effusions, with or without the addition of antiseptic irrigation with a 1-to-1,000 solution of bichloride or a three-per-cent. solution of carbolic.

Hæmatomata of the Bursæ.—The effusion into the bursa is bloody, when, as a result of some injury, there has occurred an extravasation of blood into the bursa, or when traumatic or inflammatory hæmor-

rhages have taken place from the wall of the hygroma. The treatment of these hæmatomata of bursæ is essentially the same as that for pure hygromata.

Ganglion.—The so-called ganglion generally takes the form of a round, elastic tumour, lying beneath the skin and occurring in the neighbourhood of joints, particularly those of the hand and foot. Many authorities have classed it with the hygromata of bursæ and tendon sheaths, but Volkmann is right in distinguishing the ganglion from these. He states that the ganglia have a genetic connection with the joint cavities, less often with the tendon sheaths, and are to be regarded as new growths in a limited sense of the word. The ganglion originates from a pouch-like appendage of the joint or diverticulum of the synovial membrane. The diverticulum becomes filled with thickened synovia, and may be completely cut off from the joint by obliteration of its pedicle; it practically becomes an independent cystic tumour. Ganglia are to be regarded essentially as synovial herniæ. Less frequently they originate from a kind of cystic degeneration of the capsule, from abnormity in the secretion of the synovia. There are, it is true, intermediate forms between ganglia and hygromata.

The treatment of ganglia consists in bursting them subcutaneously by pressure with the finger, or by the blow of a wooden hammer, or by means of a seal covered with a piece of linen and placed upon the tumour, or in puncturing or incising the tumour subcutaneously with a tenotome and then applying a dressing which exerts pressure. Recurrences are very common after these methods of treatment. The surest and safest procedure is free aseptic incision, followed by as complete an extirpation of the ganglion as possible. This operative treatment is entirely devoid of danger if the rules of antisepsis are carefully observed. (See also Special Surgery for the treatment of ganglion at the wrist.)

§ 100. **Gangrene (Necrosis) of the Soft Parts.**—When treating of the subjects of inflammation and injuries, we showed that they often caused death of tissue, mortification, necrosis, or gangrene. It may be well to give at this point a concise description of gangrene of the soft parts following inflammation and injuries.

Gangrene is to be regarded as a disturbance of nutrition arising from local vascular changes, diseases of the nerves, constitutional dyscrasiæ (syphilis, alcoholism, diabetes, etc.), from injuries to vessels or nerves, burns, freezing, in the course of general (bacterial) infectious diseases (pyæmia, septicæmia, typhoid fever, etc.), or from severe local inflammations, such as cellulitis, etc.

Causes of Gangrene.—The causes of tissue death are as follows: 1.

Interruption of the afferent flow of arterial blood without the development of a collateral circulation, such as may occur in the case of thrombosis and embolism, or after ligation, or in consequence of the pressure of a tumour or inflammatory exudate. 2. Interruption of the efferent flow of venous blood. 3. Interruption or stasis of the circulation in the capillaries, as a result of pressure, coagulation of the contents, or disease of the capillary walls. 4. Death of the tissue-cells without any disturbance of circulation, due to poisons, such as a snake bite, or to micro-organisms and the products of their metabolism, such as are found in infectious diseases of wounds—for example, erysipelas, cellulitis, septicæmia, etc. The various causes of gangrene are frequently more or less combined—for example, abnormally high or low temperatures cause both the cells and the vessels to lose their integrity in consequence of the coagulation of the albumen. The different tissues possess different powers of resistance against the above-mentioned causes of gangrene. Cohnheim states that a loop of intestine, for example, will die if exposed for a couple of hours to a temperature of 8° to 10° C. (45° to 50° F.), while muscles or tendons will be but little or not at all affected from a similar exposure to the same influences. The brain, kidneys, and intestine undergo necrosis within one or two hours after interruption of the afferent flow of blood, while the skin and muscles can do without circulation for ten or twelve hours. The tissues present these same differences when subjected to traumatisms. The brain is very susceptible to traumatic influences, and likewise to loss of water, while the skin, connective tissue and bones are much less so.

Local and general anæmia, venous stasis, disturbances of circulation from diseases of the vessels, heart, or lungs, or disturbance of circulation due to inflammation—in short, faulty circulation from any cause—increases the disposition to gangrene from the effects of mechanical, chemical, or thermal influences. Under these conditions, comparatively slight causes may suffice to bring about death of tissue.

Senile Gangrene.—Gangræna senilis, for example, belongs to this class of cases; it is a mortification occurring in old age and affecting the toes especially. There is usually an accompanying advanced arterio-sclerosis with chronic disturbances of the circulation, and, following some mild inflammation or slight traumatism, complete stasis takes place from coagulation of the blood in the capillaries.

Decubitus.—The bedsore, or decubitus, originates from some slight injury, particularly in patients who are paralysed; also in the course of severe febrile constitutional diseases, and in individuals with cardiac and pulmonary diseases which give rise to stases. Those regions are

particularly endangered where the skin is directly superimposed upon the bone, as in the region of the sacrum, the trochanters, scapula, olecranon, and heel. Portions of the body where skin presses against skin, as in the scrotum or labia, have but little power of resistance in individuals with circulatory disturbances.

In still other instances a weak constitution—in other words, a condition in which the cells possess slight powers of resistance—favors the occurrence of gangrene. This is seen in old people with advanced arterio-sclerosis and in those who are poorly nourished.

Noma.—This is the reason why the gangrene which spreads so rapidly on the face, the so-called cancrum oris, or noma, is particularly likely to develop in individuals who are very much reduced and in children (see Special Surgery).

Ergotine Gangrene.—Poorly nourished individuals are the ones most commonly affected by the gangrene occurring in chronic ergotism, which was not uncommon in the middle ages. The disease results from the ingestion of bread containing the ergot of rye. Ergotism is characterised by disorders of digestion, by general weakness, formication, numbness and pains in the extremities, etc. Then a rapidly spreading gangrene makes its appearance involving particularly the toes, and whole portions of the extremities, the ears, or nose, may perish. The main cause of this disease is probably the contractions excited in the small arteries by the ergotine. This produces anæmia with subsequent gangrene, especially if the individual is badly nourished and marasmic. According to Zweifel, ergotine gangrene is mainly to be ascribed to the anæsthesia caused by the ergotine, in consequence of which injurious influences of all kinds, such as traumatisms, are not perceived, and hence the individuals affected by the disease are unable to protect themselves.

Gangrene accompanying an Abnormal Composition of the Blood.—Mention should be made of the gangrene occurring when the composition of the blood becomes altered, as in anæmia, hydræmia, and diabetes mellitus. In the latter disease gangrenous inflammations, particularly of the cellular tissue, are apt to arise after the reception of slight injuries. As a result of the abnormal composition of the blood, the walls of the vessels and the cells, according to Cohnheim, have so little power of resistance that, when subjected to any slight traumatism or infection, disturbances of circulation with stasis and gangrene readily develop. But the diabetic gangrene in the vast majority of instances is caused by arterio-sclerosis of the vessels, as in senile gangrene (Heidenhain).

Nervous Gangrene.—Nervous disturbances may also favour the development of gangrene. This is the explanation of the gangrene accom-

panying leprosy (§ 85), and also that affecting paralysed portions of the body. Either the trophic nerves lose their integrity, or the necrosis of tissue and ulceration take place because the patients do not feel the irritations of the skin, and thus, as in ergotism, cannot avoid the injurious effects of such irritation.

The so-called malum perforans pedis, a punched-out, progressive ulceration of the sole of the foot, and the symmetrical gangrenes, are likewise due to nervous causes.

Symmetrical Gangrene.—According to Raynaud and Weiss, symmetrical gangrene usually appears in paroxysms, affecting the fingers, toes, and less often other portions of the body. This rare disease begins with paræsthesia and neuralgic pains; then cyanosis or anæmia develops in the parts which are involved. The gangrene generally begins in the pulp of the terminal phalanx, and either remains superficial or the entire terminal phalanx perishes. Bramann saw this symmetrical gangrene develop in three brothers of seven, ten, and thirteen years of age; it was probably the result of syringomyelia. As etiological factors, chlorosis, anæmia, hysteria, acute febrile infectious diseases (typhoid, intermittent fever, etc.), primary neuritis, etc., come into consideration. The direct cause is probably an infection of the central nervous system, and Weiss states that the preponderance of evidence points to vasomotor disturbances of nutrition in certain portions of the central nervous system. The acute gangrene, originating from disease of the vessels, is certainly to be distinguished from the purely nervous symmetrical gangrene (Socin).

Spontaneous (Angeioneurotic) Gangrene of the Extremities occurring in Youth.—In rare instances a spontaneous gangrene of the extremities will be observed which is not due to ergotism, diabetes, or syphilis, and which, in contradistinction to senile gangrene, affects strong, young individuals who are not marasmic (Billroth, Braun, etc.). The course of the disease is very tedious and extremely painful. In rare cases spontaneous recovery has been observed, but it is generally the best plan to amputate the limb, for example, by Gritti's method, at the knee, or higher up, through the thigh. Attempts at amputation nearer the periphery, in close proximity to the gangrene, are usually hopeless. Zoege-Manteuffel and others found the causation of this spontaneous gangrene to be a high grade of arterio-sclerosis, with narrowing and thrombosis not only of the main arterial trunks in the leg but also of the smaller veins. The principal nerves are usually much thickened and swollen. Angeio-sclerotic gangrene is particularly apt to occur in cold, northern regions, such as Russia.

Symptoms of Gangrene.—The symptoms of gangrene vary in general

according to its cause and location, as well as the kind of tissue which is affected. We recognise a dry gangrene—mumification, as it is called—and a moist gangrene. In dry gangrene there is a drying of the tissues as a result of a loss of water; gangræno-senilis is an example of this form. In such cases the superficial layers of tissue dry and form a gangrenous eschar. The moist gangrene is a necrosis with softening and liquefaction, and consequently is the opposite of dry gangrene. Moist gangrene is particularly likely to be accompanied by decomposition. In such cases the tissues are softened and discoloured, and present bluish-red, green, or black spots; they give forth a penetrating odour, which is due to the formation of products consisting of compounds of ammonia and fatty acids. The epidermis is elevated by blebs which are filled with a stinking liquid. Not infrequently bubbles of gas develop at the same time which contain especially ammonia, volatile fatty acids, and sulphide of hydrogen. This moist gangrene with decomposition is particularly apt to take place when the air with its germs has access to the parts and no disinfecting antiseptic dressing is employed, and consequently occurs most commonly in the superficial portions of the body and the cavities which adjoin in the lungs, etc. It is only possible for this gangrene to attack other organs by metastases, which are caused by suppurating thrombi or gangrenous pus and the bacteria they contain.

The coagulation death is another form in which gangrene presents itself. It occurs especially in necrosis of the muscles or other tissues made up of cells containing protoplasm which is capable of coagulation. According to Cohnheim and Weigert, it is dependent either upon a chemical precipitation of an albuminate or upon coagulation of the albumen by the action of a ferment which is set free. Coagulation necrosis occurs particularly in diphtheria, croup, and in the tissues surrounding colonies of bacteria.

Cohnheim states that necrosis very seldom results from the action of moulds, for the reason that the mould fungi and the bacteria of decomposition do not exist under the same conditions. A medium which supports the bacteria of putrefaction is unsuitable for mould fungi. The latter, for the most part, are incapable of development in the living body, and soon disappear (see pages 254–257).

Other symptoms of gangrene are a loss of function in the parts affected, their insensibility, and the cool or cold feeling which they exhibit on palpation.

The microscopic changes in the dead tissues vary with the form of the necrosis—that is, whether they become dry or undergo putrefaction. In the above-mentioned coagulation necrosis of Weigert the

cell nuclei disappear first. The nuclei are dissolved by the lymph, and the substance of which they consist perhaps unites with the albuminous constituents of the lymph. This phenomenon is similar to the coagulation of fibrin. The dead cells also exhibit a diminution in the size of the nuclei, vacuolar degeneration, swelling of the protoplasm of the cell, and a merging of the borders of the cells into the surrounding parts.

As regards the course of the gangrene, it either remains limited to a particular region, or it spreads. The gangrene following an interruption of the circulation or some direct traumatic disturbance of the tissue elements in an otherwise healthy individual, ordinarily remains circumscribed unless the gangrenous focus becomes infected by bacteria. On the other hand, if the health of the individual or of the affected portion of the body is faulty, the gangrene may spread (decubitus, gangræna senilis, diabetes mellitus). The infectious gangrene, in particular, which follows the development of bacteria, is very apt to spread (see pages 333–337). The boundary of the necrosed tissue is formed by the so-called line of demarcation—that is, by a demarcating inflammation and suppuration—by which the living are separated from the dead parts. A loss of substance takes place—in other words, an ulcer of the skin, the surface of the ulcer being the seat of a suppurative inflammation. This ulcer gradually purifies itself and cicatrises by the formation of granulation tissue. Not infrequently when the dead tissue is cast off, some cavity of the body is opened, and death follows. Thus, for example, perforation of the intestine or stomach by an ulcer may give rise to fatal peritonitis, and caries and necrosis of the petrous portion of the temporal bone may cause suppurative meningitis or a cerebral abscess. Other dangers of gangrene are the occurrence of hæmorrhage from the erosion of an artery, and the development of some secondary infectious-wound disease, particularly pyæmia and septicæmia, from infection by micro-organisms and the products of their metabolism.

The treatment of gangrene is conducted according to the rules laid down in §§ 70, 88, and 90 to 93, to which we must refer the reader. In gangrene of the extremities, amputation should not be performed too near the gangrenous parts—a matter which has been insisted upon before. Should a gangrene of the foot, for example, involve the dorsum or sole of the foot, Gritte's operation should be given the preference, or amputation at the thigh, because, if the leg is amputated below the knee, extensive gangrene of the flaps almost always occurs.

CHAPTER III.

INJURIES AND SURGICAL DISEASES OF BONE.

Injuries of bones: Fractures; contusions and wounds of bone; gunshot injuries of bone (see also § 124).—The inflammations and diseases of bone: Acute inflammations of bone; acute periostitis; acute osteomyelitis; acute ostitis.—Metastatic inflammations of bone.—Embolic foreign-body inflammations in mother-of-pearl turners and workers in woollen and jute mills.—The chronic inflammations of bone (tuberculosis, syphilis, etc.): Chronic periostitis, osteomyelitis, and ostitis.—Caries.—Necrosis of bone.—Rhachitis.—Osteomalacia.—Atrophy and hypertrophy of bone.—Increased longitudinal growth.—Giant growth.—Acromegaly.—Tumours of bone (see Tumours, Chapter V).—Parasitic tumours of bone (echinococcus; cysticercus cellulosæ).

§ 101. **Fractures.**—The word fracture needs no further definition; it means both the act of breaking a bone and the state of being broken. Fractures are very common, and, according to Bruns, they make up more than a seventh part of all injuries which come under observation, and are about ten times more common than dislocations.

Cause of Fractures.—Every fracture presupposes the action of some mechanical violence upon the bone in question which is great enough to overcome the strength and the power of resistance which the bone possesses. The majority of fractures are produced by external violence; and, according to the way in which the external violence acts, we distinguish two main groups, the direct and the indirect fractures.

Direct and Indirect Fractures.—The *direct* fractures are those in which the bones are broken at the point where the violence, such as a blow, a thrust, a gunshot, the wheel of a waggon, etc., is applied. If, on the other hand, the break is situated at a point some distance from the place where the violence has been applied—in a fall, for example—we call such a fracture an *indirect* one. It is evident that in the direct fractures especially the soft parts will receive more or less injury, which varies from a slight contusion to a complete mangling of all the soft parts surrounding the broken bone. The indirect fractures are most commonly the result of a bending of the bone beyond the limits of its elasticity by bringing the two ends of the bone nearer together, as in a fracture of the thigh from a fall upon the feet. In other instances

indirect fractures are the result of forced compression and crushing, as in fractures of the vertebræ from a fall upon the buttocks; or of violence applied through a fulcrum with crushing, as in fracture of the olecranon by hyperextension at the elbow joint; or of traction, tearing, or rotation (torsion). The lower end of the radius, for example, is caused to break by the traction exerted by the anterior ligament of the wrist in forced dorsal flexion. Great interest attaches to the production of indirect fractures of the skull by a tearing apart of the bony parts which are put on the stretch, or by the vertebræ being driven into the occipital foramen (Messerer). In indirect fractures it sometimes happens that the fragments are more or less firmly forced into one another (so-called impacted fractures). The injuries to soft parts occurring in indirect fractures are produced by more or less pointed fragments which perforate the skin (transfixion fractures), or wound muscles, vessels, or nerves, etc.

Fractures resulting from Muscular Action.—Sometimes fractures are the result of excessive muscular action. These usually take the form of a tearing off of some small bony prominence, like the coracoid process of the scapula, or the greater tuberosity of the humerus. The fractures, which often complicate dislocations, are frequently produced in a similar manner; for example, the ilio-femoral ligament may tear off a piece of bone from the femur at its point of attachment (cortical fracture). It only rarely happens that large, hollow bones are broken by muscular traction. In this category come the fractures of the femur sustained in playing at ninepins, or in administering a kick which misses its object; also fractures of the humerus from violent movements of the arm, transverse fractures of the patella (see Special Surgery), and fractures of the clavicle from brandishing a whip, or fractures of the ribs as a result of violent attacks of coughing in old people, etc.

Intra-uterine Fractures.—Intra-uterine fractures in the fœtus are produced by the infliction of great violence to the abdomen of the mother. Varying with the length of time which elapses between the reception of the injury and the birth of the child, the fracture will be found to be comparatively recent, in process of repair, or already healed. The bending or fracture of bones due to fœtal rhachitis or syphilis are not of traumatic origin. Other intra-uterine bony deformities are also met with which at first sight look like badly united intra-uterine fractures, but are, in reality, defects in development. In this class of cases belong the malformations which are the result of defects in ossification, such as absence of the fibula, etc.

Fractures during Birth.—In other instances infants sustain fractures during birth from unskilful operative midwifery or from the act of

parturition itself. The bones of the extremities may be broken through the diaphysis or in the region of the epiphysis while an arm is being freed or version or extraction performed, but fractures of the bones of the head are mainly due to the use of the forceps. In very rare cases fractures of malposed extremities result from contractions of the uterus. The latter are more likely to cause injuries to the skull, especially in cases of narrow pelvis or anomalies of the child's head. In the milder cases there will be a depression with or without fissure, while in severe cases actual fractures of the skull occur.

The amount of resistance of which a bone is capable bears a very important relationship to the production of fractures. The strength of a bone varies greatly in different individuals, as does also the strength of different bones in the same individual, and even different parts of the same bone exhibit variations in resisting power.

Natural Solidity of the Bones.—The natural strength and mechanical capabilities of bones, so important in the etiology of fractures, have recently been investigated by P. Bruns, Reiff, and others, and the attempt has been made to found the etiology of fractures upon a physical basis. The elasticity of the individual bones, i. e., their ability to resume their original shape after it has been changed by external force, and the limits within which this is possible—in other words, the limit of their elasticity—have been computed. The strength or the resistance which the bones offer to violence in its various forms, such as pressure, traction, bending, rotation, or torsion, has also been ascertained. It has thus been possible to determine definite values for the elasticity and solidity of the texture of the bone substance, and for the bones in their entirety, which values express the amount of this or that kind of violence required to produce fractures; and hence it is perfectly correct to designate fractures according to the nature of the traumatism, as fractures from traction or tearing, from compression, bending, or torsion.

Measurements showing the Strength of Bones.—As regards the strength of a bone due to its structure, the values naturally vary in different bones and in different individuals, but the general rule holds that the compact bone substance is always stronger than the spongy.

The tensile strength of the compact bone substance in a fresh condition and during middle life amounts, according to Rauber and Messerer, to 9·25 to 12·21 kilogrammes per square millimetre, or about the same as that of brass and cast iron. The compression strength is still greater (12·56 to 16·8 kilogrammes per square millimetre), or double that of wood, granite, or lead. The torsion strength averages 8 kilogrammes per square millimetre.

The strength of spongy bone substance is much less, the compression strength of the spongy portion of the femoral condyles amounting, according to Messerer, to only 0·96 kilogramme per square millimetre, that of the bodies

of the vertebræ to 0·84, being in middle life 0·62 to 0·92, and in old age only 0·22 kilogramme per square millimetre.

The strength of the bone as a whole is a matter of great practical importance as regards the etiology of fractures. The tensile strength of the humerus, for example, according to Messerer, amounts to 533, and of the femur to 694 kilogrammes per square millimetre. He found that the compression strength of the individual bones decreased in the following order: Tibia, femur, humerus, radius, ulna, clavicle, fibula. Compression directed through the longitudinal axis caused fracture of the shaft, the tibia being the strongest and breaking under a pressure of 1,650 kilogrammes, the femur on the average in man requiring a pressure of 756 kilogrammes, the radius in man 334 kilogrammes, in women 220 kilogrammes. Frequently the break does not take place at the point most endangered—the middle of the bone—but at one or other articular extremity by compression.

A great number of fractures are, as is well known, the result of bending (Bruns). The limit of bending possessed by bones varies in different years of life, and, according to Messerer, it amounts to between 1,040 and 1,980, and reaches its maximum at middle age. In men 400 kilogrammes, and in women 263 kilogrammes, will cause a fracture of the femur from bending.

The torsion elasticity amounts to about a third of the bending elasticity. A fracture of the femur by torsion, according to Messerer, is produced by 89 kilogrammes, of the clavicle by 8 kilogrammes. The femur possesses the greatest torsion strength, the clavicle, ulna and fibula the least.

Messerer's experiments on the skull show that the diameter, which is not subjected to pressure, becomes, in the majority of instances, gradually though very slightly lengthened in proportion as the pressure increases. The decrease of the diameter in the direction of the pressure is not evenly distributed over the whole skull, as only the part directly subjected to pressure bends inwards. The skull withstands a greater amount of force in a sagittal than in a transverse direction. The average pressure required to produce a longitudinal fracture averaged 650 kilogrammes; for a transverse fracture, 520 kilogrammes. In most instances the base of the skull proved to be the weakest spot, that portion of it bursting which was under the greatest tension; transverse pressure caused a transverse fracture, and longitudinal pressure a longitudinal fracture. The average pressure, acting through the vertebral column, which was required to produce a fracture of the base amounted to 270 kilogrammes.

In young persons the sternum could be driven completely back to the vertebral column by sagittal pressure upon the thorax without producing a fracture. A pressure of 250 kilogrammes exerted in a sagittal direction upon the pelvis generally caused a symmetrical fracture of the os pubis; a transverse pressure of 180 kilogrammes exerted upon the crest of the ilium, caused a diastasis of the sacro-iliac joint.

According to Rauber, the strength of bones is, as a general thing, diminished by heat.

Changes in the Strength of the Bones.—The normal strength of bones is affected very materially by various circumstances, such as their shape, their length and thickness, the direction of their longitudinal axes,

whether the latter approach the perpendicular or show deviations from it, etc. There are also various pathological conditions which lessen the resisting powers of bones and produce an abnormal fragility (osteopsathyrosis), causing the bones to break spontaneously or upon the application of a very slight amount of violence. In this category belongs the atrophy of bone which occurs in advanced age, or in the course of chronic diseases, or after paralysis, etc. The strength of the bones usually increases till middle life, and from then on gradually decreases (senile atrophy). The bones also atrophy when they are not used, as in the course of chronic diseases, in paralysis, etc. (atrophy of disuse).

Neurotic or Tropho-neurotic Atrophy.—In addition to the atrophies of senility and disuse, Weir Mitchell, Charcot, and P. Bruns have directed attention to the occurrence of neurotic or tropho-neurotic atrophies of bone which are due to affections of the central nervous system. In this class of cases belongs the fragility of bone which accompanies tabes dorsalis and chronic cerebral disease, such as progressive paralysis, and in fact all forms of mental disease and paralysis. Rauber found that the tibia of a paralysed extremity supported a weight of 198 grammes, while the bone on the non-paralysed side held a weight of 281 grammes.

No further explanation is required for the fragility which is the result of disease of bone with subsequent loss of substance, such as occurs, for example, in tubercular and syphilitic diseases, suppuration, or necrosis; tumours, such as cysts, sarcoma, or carcinoma; from the presence of echinococcus; or abnormal softness of structure (rhachitis and osteomalacia). An abnormal weakness and fragility of the bones is also present in scurvy, a disease which was at one time very common.

Idiopathic Osteopsathyrosis.—But in addition to these various kinds of fragility of bone due to this or that cause, there is also an idiopathic form, the etiology of which is as yet completely unknown. In such patients, who in all other respects seem perfectly well, the slightest exhibition of violence, such as a sudden movement, a slight thrust, or even turning over in bed, suffices to produce a fracture of bones which externally appear entirely normal. The malady is congenital in a number of cases, and sometimes a pronounced hereditary taint runs through many generations. In other cases the disease develops in early youth or later, and then usually persists throughout life. In this idiopathic form of fragility no gross changes are found in the bones. The most probable cause of this disturbance of the nutrition of the bones is a change in the composition of their ground substance. The observations of Blanchard, in particular, show the frequency of fractures in

individuals with idiopathic fragilitas ossium. He had one case of a twelve-and-a-half-year-old girl who had had, since the second month of her existence, forty-one fractures from the effects of very slight violence; she had had fourteen fractures of the right and eleven of the left leg. Arnott had a patient fourteen years old who since the third year of life had had thirty-one fractures, of which seven were of the right thigh and nine of the right leg below the knee. It is rather remarkable that the repair of fractures in idiopathic osteopsathyrosis usually takes place easily and quickly.

Strength of the Epiphyses.—As long as the diaphysis and the epiphysis, during the period in which the bones are growing, are connected by a cartilaginous symphysis, the resistance at this point may be diminished by various processes, especially those of an inflammatory nature, and a spontaneous separation of the epiphysis may thus be produced. Under this heading came the epiphyseal separations due to syphilitic processes, to scurvy, and to the primary infectious inflammations of the bone marrow (osteomyelitis).

The Various Kinds of Fractures—Incomplete Fractures, Depressions, Fissures.—We distinguish complete and incomplete fractures according to the extent to which the bone is divided. To the incomplete fractures belong the green-stick fractures and the fissures. A green-stick fracture occurs in the bending of a bone, by which the cortical substance on the convex side is broken while on the concave side it is only pressed in (Fig. 331). The depressions occurring on the skull, for example, as a result of pressure or a blow, can be regarded as incomplete fractures (Fig. 340). The fissures (Fig. 332) are comparable to a crack in a glass or a plate, and occur especially in the brittle bones of adults, less often in those of children, and are frequently combined with complete fractures which are received at the same time. They are particularly common on the skull. In gunshot fractures the bones involved often sustain numerous fissures. It is of great practical importance to note that fissures of this description, especially when the fracture is near a joint, sometimes run through the articular extremity of the bone and penetrate into the neighbouring joint. If after a gunshot fracture, for example, suppuration should take place at the point where the bone has been broken, this suppuration may travel along the fissure into the joint.

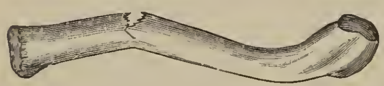


Fig. 331.—Incomplete fracture (green stick fracture) of the clavicle.

Complete Fractures.—A fracture is complete when the bone breaks into two or more pieces which are completely separated from one another; division of the bone into two fragments takes place most

commonly. According to the direction of the line of fracture with reference to the longitudinal axis of the bone we recognise transverse, oblique, spiral, and longitudinal fractures. The pure transverse fractures are generally produced by direct violence, and are not very common if we disregard the separations of the epiphyses. The most common fractures are the oblique, which are almost always the result of indirect violence or forcible bending. The fracture having the form of a clarinet mouthpiece, and first described by French writers (*fracture en bec de flûte*), is a pronounced oblique fracture which occurs especially in the tibia and femur, and was produced by W. Koch by rotation combined with a vertically directed blow (Fig. 333). The spiral or torsion fracture (Figs. 334, 335) is produced, according to the experiments of Koch and Bruns, exclusively by twisting, the line of fracture having the shape of a spiral curve. The prognosis of a spiral fracture is more unfavourable than an oblique one, for the reason that the fractured surfaces are very extensive and the points of one of the fragments may readily penetrate the skin or be driven into the other fragment and cause considerable crushing of the bone marrow.

Fig. 332.—Fissures in the femur.

Longitudinal Fractures.—Longitudinal fractures, or the division of a bone into two fragments with the line of fracture running its entire length, are very rare in the long, hollow bones, and most longitudinal fractures are merely extreme forms of oblique fractures. Krönlein has described a longitudinal fracture of the humerus and three longitudinal fractures of the phalanges of the fingers, and he could find in literature only one longitudinal fracture through the whole length of the tibia, which was recorded by Gädücke. Longitudinal fractures have been noted somewhat more frequently in the short bones (patella, vertebræ).

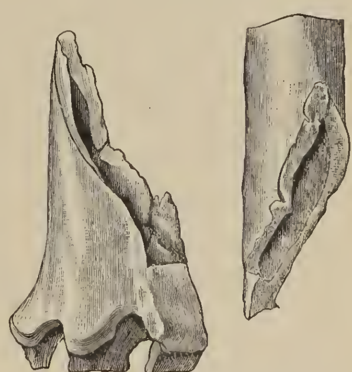


Fig. 333.—Fracture having the shape of the mouth-piece of a flute (*fracture en bec de flute*).

A Multiple Fracture.—In a multiple fracture (fractura multiplex) the bone is either broken at two or three different points (double, threefold fracture), or the bone is shattered at one point into many fragments (comminuted fracture—fractura comminuta.) The term multiple fracture also includes fractures sustained simultaneously by several bones, particularly those which are placed parallel to one another in the forearm and leg. The shape of the multiple breaks in the same bone varies, of course, very much, but a few typical forms are frequently observed. These typical forms include especially the T- and Y-shaped fractures, occurring at the epiphyseal extremities of the long bones (Figs. 336, 337). In the T fracture (Fig. 336) there is a transverse and a longitudinal break; in the Y fracture two oblique breaks, the production of which has been studied experimentally by Gurlt, Madelung, and Marcuse. In fractures from bending and from torsion a cuneiform or rhombic piece is sometimes broken out of the continuity of the bone (Bruns). The outward appearance of a comminuted or splintered fracture (Fig. 338) presents great variations in regard to the number, shape, and size of the individual fragments. In the worst cases there will be found at the point of fracture a peculiar soft bag of skin like a sack filled with crepitating fragments of bone, or the bones and soft parts are crushed into a bloody pulp, as is the case, for example, in "run-over" accidents.

FIG. 334.—Spiral fracture of the tibia (W. Koch).

FIG. 335.—Spiral fracture of the femur (W. Koch).

Condition of the Soft Parts in the Neighbourhood of a Fracture.—The condition of the soft parts in the neighbourhood of a fracture is exceedingly important for the prognosis. All fractures in which there

is a wound of the soft parts penetrating to the line of fracture are called compound or open fractures, and must be carefully distinguished from

Fig. 336.—T-shaped fracture of the lower end of the femur, caused by a fall upon the knee (Bruns).

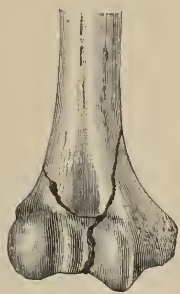


Fig. 337.—Y-shaped fracture of the condyles of the humerus, caused by a fall upon the elbow (Bruns).

Fig. 338.—Comminuted fracture of the lower end of the humerus, caused by a fall upon the elbow.

the subcutaneous or simple fractures—i. e., those in which the outer covering of the soft parts has not been opened. In the days before antisepsis the compound or open fractures very often terminated fatally from pyæmia and septicæmia. The extent of the wound of the soft parts varies from an insignificant puncture to an extensive crushing and laceration of the tissues. The wound is produced either by the same violence that produces the fracture, as in gunshot or run-over injuries, or the skin is opened afterwards by injudicious movement of the fractured extremity—in transportation of the patient, for example—or as a result of gangrene, etc. The open, comminuted fractures, the compound fractures of joints, particularly those found in gunshot wounds, and extensive mangling of the bones and soft parts in run-over accidents, are the most unfavourable compound fractures.

Separations of the Epiphyses.—In young subjects, as long as the diaphysis and epiphysis are connected by a cartilaginous symphysis, traumatic separations of the epiphyses may occur, which, according to Bruns, are most common in the case of the lower epiphysis of the femur, then in the lower epiphysis of the radius and in the upper epiphysis of the humerus. The *spontaneous* separations of the epiphyses in consequence of inflammatory or suppurative processes must be carefully distinguished from the traumatic separations. The traumatic separations are mainly the result of exaggerated movements in joints. As a result of these exaggerated movements in adults, dislocations of the joints take place, but in children fractures through the fragile epiphyseal cartilage or in its neighbourhood. This is the reason why traumatic dislocations are so very rare in young children. In infants,

separations of the epiphyses, particularly *inter partum*, are brought about by violent or unskilfully performed obstetrical operations (turning, extraction). The age limit within which epiphyseal separations may occur varies with the different epiphyses. The observations hitherto recorded, for example, show that the twenty-fifth year of life is the latest period at which a traumatic separation occurs in the upper epiphysis of the humerus.

Symptomatology and Clinical Course of Fractures.—The symptoms of fractures are partly objective and partly subjective. The most important objective symptoms are: 1. The abnormal mobility of the bone. 2. Crepitation—i. e., the rubbing sound which is heard, or, more correctly, felt, when the fractured surfaces are rubbed together. 3. The deformity of the broken bone, or rather of the part of the body to which it belongs, in consequence of the displacement of the fragments. Abnormal mobility and crepitation are best demonstrated by seizing both fragments in the neighbourhood of the line of fracture and moving them in opposite directions. Rotary movements may also be tried in cases of fractures of the articular ends of bones. Abnormal mobility and crepitation are absent in impacted fractures, in fractures with sharp, toothed fragments which interlock, and in incomplete fractures. Crepitation will also be absent when the fractured surfaces are not in immediate contact with one another. The soft friction sound which is sometimes emitted by dried extravasations of blood or by inflammatory processes—of the tendon sheaths, for example—must be carefully distinguished from the harder bony crepitus. Deformity is caused by the displacement of the fragments. We recognise the following four principal kinds of displacement, which sometimes occur separately and sometimes combined in various ways: 1, Angular displacement (dislocatio ad axin, Fig. 339, *a*); 2, lateral displacement (dislocatio ad latus, Fig. 339, *b*); 3, displacement of the fragments in a longitudinal direction (dislocatio ad longitudinem, Fig.

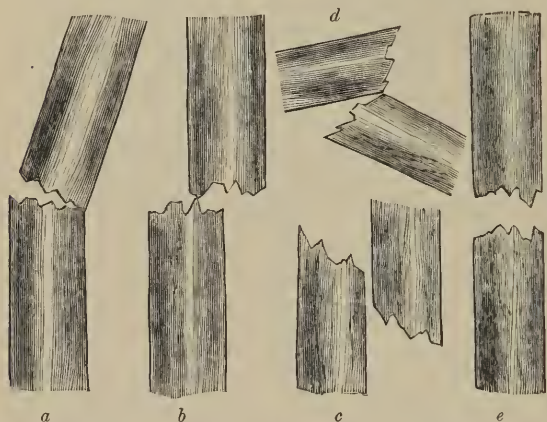


Fig. 339.—The different varieties of displacements of the fragments.

339, *c*); and, 4, rotation of the fragments on their longitudinal axis (dislocatio ad peripheriam). The so-called overriding of the fragments —the pushing of one over the other (Fig. 339, *d*)—is a combination of the dislocatio ad latus and ad axin, sometimes with the addition of a dislocatio ad longitudinem. The so-called diastasis of the fragments (Fig. 339, *e*) and the reverse or impaction of the fragments are to be regarded as a dislocatio ad longitudinem. There is a variety of displacement, occurring mainly in fractures of the skull, which is called depression of the fragments (Fig. 340, *a*, *b*).

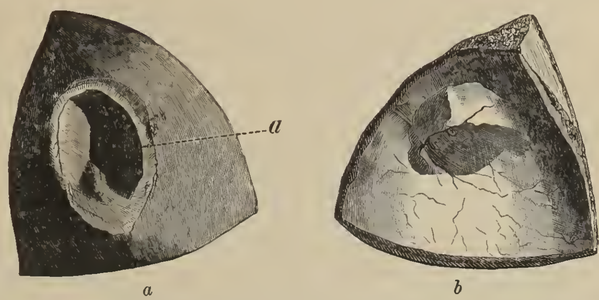


Fig. 340.—*a*, Fracture of the skull with depression, seen from the outside (caused by a fall upon a pointed stone); *b*, the same fracture seen from within (Bergmann).

The different displacements are sometimes primary and produced by the fracturing force, and at other times secondary, occurring sooner or later after the injury as a result of voluntary or involuntary muscular contractions, of transportation, examination, the position the injured member is caused to assume, of defective dressings, etc.

Subjective Symptoms of Fracture—Pain and Disturbance of Function. —The subjective symptoms of fracture are pain and disturbed function. By pain is understood primarily the great tenderness of the bone at the line of fracture, especially when pressure is applied at this point. Above and below the line of fracture the bone is not at all tender on pressure. This linear character of the pain, so to speak, is of diagnostic importance in doubtful cases.

The disturbance of function which occurs in fractures needs no further explanation. In consequence of the division of the bone, an extremity, for example, loses its bony support, and the muscles their fixed points of attachment. The amount of functional disturbance depends principally upon the amount of the abnormal mobility, displacement, and deformity, and also upon the nature and location of the fracture. If, for instance, only one bone is broken in a limb which contains two, the functional disturbance may be very slight, varying with the importance of the broken bone. Thus in fractures of the fibula the patient will still be able to walk, and in fractures of the ulna use of the forearm is possible, especially pronation and supination. The disturbance

of function is also slight in the case of impacted fractures, and patients with an impacted fracture of the neck of the femur can stand and walk. Moreover, in impacted fractures of the articular extremities of other bones the mobility of the joint involved is often very little or not at all disturbed.

Fever in Subcutaneous Fractures.—Apart from these local symptoms at the point of fracture, we sometimes observe fever following the reception of subcutaneous fractures. The thermometrical measurements made by Volkmann, P. Bruns, Grundler, and myself, show that, as a rule, more or less fever exists, particularly during the first few days after the injury. The height of the fever varies between 101·3° and 102·2° F., though in rare instances the temperature may rise to 104° F. In twenty-five out of twenty-six cases of subcutaneous fracture Grundler observed a rise of temperature to 99·1° F. The cause of this febrile movement is ascribed by Bergmann, Wahl, and Angerer to the absorption of dead tissue elements, and especially of fibrin ferment and other ferments which are formed in the extravasated blood near the point of fracture, as described in § 62. The fever is essentially a ferment intoxication.

Suppuration in Subcutaneous Fractures.—As a rule, subcutaneous fractures heal without suppuration, and the latter only occurs when micro-organisms gain access to the point of fracture through some small cutaneous wound or through the blood; the extravasated blood and the injured (necrotic) tissues furnish a favourable nutritive medium for their development.

Course of Compound Fractures.—The course of compound fractures varies greatly, according to the size of the wound in the soft parts, the condition of the fragments, and the treatment. The favourable cases are those with a small cutaneous wound, which, before infection occurs, heals by immediate adhesion of the opposed wound surfaces, or beneath a scab *per primam intentionem*. Under these conditions they run a course like that of a subcutaneous fracture.

The worst cases of compound fractures are those in which the soft parts are so extensively destroyed that the preservation of the limb is entirely out of the question. To these may be added the cases in which there is extensive splintering of the bones or a perforation into a joint or one of the cavities of the body. But as a general thing it is more the extent of the injury to the soft parts than the nature of the injury sustained by the bones which determines the severity of the case. Any simple division of the bone which is accompanied by great destruction of soft parts is to be regarded, in point of prognosis, as a more severe injury than a splintering of bone which is in itself considera-

ble but is not accompanied by any great amount of injury to the soft parts.

The clinical course of a compound fracture is, moreover, affected in a very marked degree by the way in which it is treated. The sooner a compound fracture is placed under the protection of antiseptic treatment—i. e., the sooner the wounded soft parts and the seat of the fracture are thoroughly disinfected, the drainage of the wound attended to, and an antiseptic dressing applied—the sooner is a satisfactory course of repair guaranteed.

If we leave out of consideration the compound fractures which heal antiseptically, the local symptoms, in the majority of cases, consist in a more or less severe inflammatory swelling in the parts surrounding the wound and point of fracture. The discharge from the wound is at first thin and discoloured by blood. In the aseptic cases it is limited in amount and does not become suppurative. In the cases which do not run an aseptic course the discharge is plainly purulent or even sanious—in other words, it undergoes decomposition in consequence of infection by micro-organisms. The production of suppuration and putrefaction is favoured by extensive destruction of the soft parts at the time of the injury. This putrefactive suppuration can, if the escape of the discharge is prevented, readily take on a spreading character in the shape of a progressive gangrenous cellulitis, which may endanger the preservation of the limb and of life. If the suppuration or putrefaction runs a favourable course, the surface of the wound gradually "purifies" itself—i. e., the superficial gangrenous portion of the wound is slowly cast off by a demarcating suppuration, red granulations make their appearance, and the wound fills with germinal tissue which then ossifies. The suppuration around the ends of the fragments which have become necrotic, or around splinters, is sometimes very tedious, and there is always the possibility of the pus burrowing or giving rise to infectious suppuration in the periosteum or the bone marrow, or causing lymphangitis, phlebitis, etc., and thus death from septicæmia or pyæmia. By long confinement to bed, or from protracted fever or profuse suppuration, the patient may become so exhausted and such serious degenerations of the internal organs may occur, that life is imperilled.

Throughout the entire period occupied by the process of repair, the temperature of the patient should be taken two or three times a day, and at every new rise of temperature the wound should be carefully examined to determine the presence of any disturbance, such as a burrowing of pus, a deeply located spreading inflammation and suppuration, etc.

Not infrequently, after a compound comminuted fracture has healed, fistulæ will persist for a long time; they indicate the presence of some encapsulated, necrotic piece of bone—a so-called sequestrum.

Condition of the Urine in Fractures.—As a result of the absorption of blood from the point of fracture, the urine very frequently contains urobilin, a derivative of the colouring matter of blood, which, on shaking the urine with a solution of chloride of zinc and ammonia, causes the urine to assume a yellowish-green fluorescence. Fat is also very often found in the urine; it is derived as fluid fat from the crushed medullary portion of the bone and the fat in the neighbouring soft parts, and, passing through the circulation, is excreted by the kidneys. We shall learn further on that it can sometimes accumulate to a dangerous degree in the lungs and brain. The amount of fat in the urine varies greatly, depending upon the severity of the injury to the marrow and soft parts; in some cases it is found only in traces, while in others there may be large quantities of it. Occasionally it is so abundant that it is visible in the form of smaller or larger drops on the surface of the urine. Most commonly the fat is mixed with the urine in the form of an emulsion, and Scriba maintains that this occurs in almost every case of fracture. After the urine has been allowed to stand for some time a white layer develops on its surface, which the microscope shows is made up of small and minute fat drops. According to Scriba, the excretion of fat by the kidneys takes place periodically, corresponding to the sweeping away of the fat emboli in the lungs. This is the reason why the urine during the repair of a fracture changes so much, containing fat for several days and then being free from it for five to six to ten days. The excretion of fat begins on the second to the fourth day after the injury, and usually ceases on the twentieth to the twenty-fourth day.

In addition to fat, the urine of patients with fractures sometimes contains albumen and casts. The amount of albumen and casts is greatest in the first twenty-four to forty-eight hours, and the condition lasts about four to six days. Besides hyaline casts Riedel found other casts studded with numerous brown granules like those which occur in bilious pneumonia and other diseases accompanied by degenerative changes in the blood. These brown casts are irregular in their occurrence in fractures and are frequently entirely absent, while in other instances they appear in great numbers. Riedel ascribes the origin of these brown casts to the absorption of red blood-corpuscles at the point of fracture. They are obtained experimentally by producing fractures artificially, by injecting blood into the peritoneal cavity, and by injecting Köhler's fibrin ferment. Both Orth and myself have occasionally found very large collections of red corpuscles and of the colouring matter of blood in the lymph glands and in the internal organs. The hæmatogenous jaundice which sometimes occurs is similarly explained by the presence of disintegrated red corpuscles and blood-colouring matter in the circulation.

Repair of Fractures.—Fractures either heal *per primam* or *per secundam intentionem*, in the same way as described in § 61 for wounds of soft parts. Subcutaneous fractures, as a rule, heal *per primam intentionem*, while compound fractures heal *per secundam intentionem*.

As we remarked above, suppuration takes place in exceptional cases of subcutaneous fractures from the entrance of micro-organisms through an abrasion in the skin or by means of the blood-vessels.

Whether a fracture heals with or without suppuration, the anatomical changes are essentially the same, and consist, briefly speaking, in the formation at the point of fracture of cellular tissue, which is at first soft, and later is gradually changed into bone by the ossifying action of the periosteum and marrow. The ossifying tissue at the point of fracture is called the *callus*.

Anatomical Changes in the Formation of the Callus.—The anatomical changes which take place in the formation of the callus are histologically an ossifying periostitis and osteomyelitis. The extravasated blood at the point of fracture plays no active part in the formation of the callus, and is gradually supplanted by a germinal tissue rich in cells and vessels. The outer or periosteal callus originates from the inner layer of periosteum, which contains osteoblasts, while the marrow forms the inner or medullary callus (Fig. 341). The callus between the broken ends of the bone is called the intermediary callus, and is mainly produced by proliferation of the periosteal germinal tissue between the fractured surfaces; the tissue of the opened Haversian canals and the marrow only shares to a slight extent in the formation of the intermediary callus. The view which formerly prevailed—namely, that the surrounding soft parts were capable of contributing to the formation of the outer callus—is untenable in the light of our present knowledge of the normal development of bone.

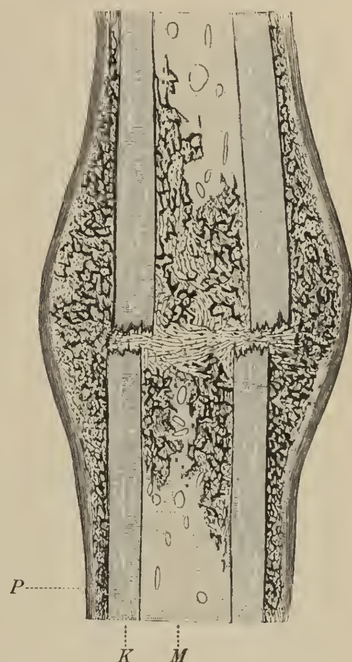


FIG. 341.—Longitudinal section through a fracture of the femur three weeks old: P = periosteum; K = bone; M = medulla. Periosteal callus and medullary callus. The intermediary callus consisting of periosteal granulation-tissue, which is ossified only in some places and is partly cartilaginous.

The Normal Formation of Bone—The Development of Bone.—It is now generally believed that the normal development of bone is mainly the result of successive appositions of bone substance due to the activity of the medullary tissue, the cells of which change into specific bone-forming cells—the so-called osteoblasts (Gegenbaur, Fig. 342).

The medullary tissue may spring either from the periosteum or from cartilage. The periosteum or perichondrium (in the cartilaginous bones of the embryo) is made up of two layers, an outer fibrous layer and an inner layer of osteoblastic cells. In this latter layer medullary spaces develop, and in them the osteoblasts from an active formation of cells and growth of vessels. In addition to the periosteal or perichondrial bone formation we recognise an endochondrial bone formation in the cartilage of embryonic bone; this takes place especially in the growth of the long bones at the epiphyseal junction. Medullary cavities develop here also, and a portion of the medullary cells change into osteoblasts. Opinion differs as regards the importance of the cartilage cells in the endochondrial formation of bone, Virchow and others believing that the cartilage cells change into medullary cells and osteoblasts, while Gegenbaur and Strelzoff maintain that the cartilage cells, as such, perish, and take no part in the formation of bone. The latter authorities hold the view that the osteoblasts are always derived from the marrow or the osteoblastic layer of the periosteum. Maas's view that the colourless blood-corpuscles are capable of forming the callus seems to me untenable.

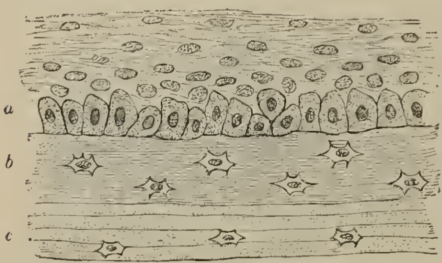


FIG. 342.—Periosteal formation of bone from osteoblasts *a*; *b*, newly formed bone; *c*, old bone. × 300.

The transformation of the osteoblasts into bone tissue is brought about by a change of the greater part of the protoplasmic material into a tissue which appears homogeneous, but is really made up of fine fibrils, which, after taking up bone salts, forms a lamellated ground substance. Here and there cells persist as bone cells, which are enclosed by the newly formed bone in serrated cavities, having fine processes radiating from them. These are the so-called bone-corpuscles. Meyer and the mathematician Cullmann were the first to show that the bony structure and trabeculæ are arranged according to mechanical laws.

Interstitial Growth of Bone.—In addition to this appositional growth of bone from the periosteum and medulla, Ollier, Virchow, and others have called attention to the occurrence of an *interstitial* growth—i. e., an expansion of the bone substance already formed. This was demonstrated by driving pegs and boring holes into growing bone.

Artificially Increased Growth of Bone.—Under such pathological conditions as necrosis, chronic inflammatory processes, compound fractures,

chronic joint inflammations, etc., as a result of irritation of the epiphyses, an increased growth of bone is observed, especially in the long axis. The longitudinal growth can be artificially increased and shortening compensated for by driving ivory pegs into the bone, or tying off the extremity with an elastic tourniquet, or by other forms of irritation acting upon the diaphysis in the neighbourhood of the epiphysis, from which the effects are transmitted to the epiphyseal cartilage (Ollier, Langenbeck, etc.). In the case of a compound fracture which healed slowly with suppuration, I saw a shortening of eight centimetres in the beginning changed to three centimetres in the course of about one to one and a half year as a result of an abnormal stimulation of the growth. Sometimes, even in subcutaneous fractures, the shortening which may exist at first disappears after a year or two by augmented longitudinal growth.

Absorption of Bone Substance.—Simultaneously with the new formation of bone there is constantly taking place, on both the outer and inner surface of the bone, an absorption of bone substance which is brought about by special cells called osteoclasts (Kölliker). These osteoclasts (Fig. 343) usually have the appearance of polynucleated giant cells, and, according to Kölliker, are derivatives of the osteoblasts; but Wegner maintains that they are formed by proliferation of adventitia cells,

FIG. 343.—Lacunar absorption of bone by osteoclasts (O), which lie in the Howship's lacunæ. × 250.

and Recklinghausen, that they originate from white blood-corpuscles. According to Pommer, the cells of the adventitia of the blood-vessels, the endothelial cells of the perivascular lymph spaces, and of the Haversian blood-vessels themselves—in short, the protoplasm of all the cells lying near the bone substance—are capable, under certain conditions, of taking on osteoclastic functions. Pommer states that the subsequent history of the osteoclasts, as well as their derivation, varies, and that osteoblasts or other cells may be made from them. He ascribes the cause of the production of the osteoclasts to the increase in the local blood pressure. The action of the osteoclasts is entirely local, the bone disappearing in the form of small pits or lacunæ (Howship's lacunæ, lacunar bone resorption, Fig. 343). The

osteoclasts probably form carbonic acid, by which the lime salts are dissolved, and the rest of the ground substance is assimilated by the osteoclasts or absorbed by the blood or lymph current.

The Ossification of the Callus.—The ossification of the callus takes place in precisely the same way as in the development of bone. The germinal tissue either ossifies as such, or there is first a production of hyaline or fibrous cartilage. In the deepest layers of the periosteal germinal tissue, and hence close to the bone, at a little distance from the broken ends and in the neighbourhood of the normal intact periosteum, there appear by the third or fourth day small collections of bone-like, "osteoid" tissue. A network of bony trabeculæ, with enclosed medullary spaces, gradually develops. During the second week the formation of the periosteal callus is so far advanced that it consists of a great number of osteoid and osteal trabeculæ—in other words, the two fragments are bound together by a young osteophyte made of wide-meshed bone tissue. At the end of the third week (Fig. 341) the periosteal callus usually consists of fairly firm, spongy bone. Simultaneously with the formation of the periosteal callus the internal (myelogenic) callus develops in the medulla of the bone in the same way. On the inner surface of the cortex a trabecular system of osteoid tissue is formed, which gradually changes into true bone by the deposition of bone salts. The size of the medullary callus varies greatly, oftentimes filling the entire medullary cavity, while in other instances it may only develop to a slight extent. In the medullary callus also, particularly in the neighbourhood of the point of fracture, hyaline and fibrous cartilage is found, though not so constantly nor in so large amounts as in the periosteal callus. The so-called *intermediary* portion of the callus, which lies between the broken ends, develops, as we remarked before, principally from the periosteum.

Retrogressive Metamorphosis of the Callus.—At the outset the callus is made up of spongy bone rich in marrow. This so-called provisional callus is then transformed into the permanent bone cicatrix by becoming more compact, decreasing in circumference, and becoming smooth on its surface. This involution of the callus may reach such completeness that the bone cicatrix is later on scarcely visible. If the medullary cavity was closed by the medullary callus it may again become free by absorption of bone. Wherever the bone substance formed in the ossification of the callus is not functionally necessary it is absorbed; while, on the other hand, apposition of bone substance takes place in those parts of the callus where they are necessary for the firmness of the bone cicatrix. In this way the structure of the bone

at the point of fracture is regenerated as completely as possible and as the laws of statics demand.

Billroth, Volkmann, Ollier, Bruns and others have been instrumental in elucidating the subject of the formation of the callus, but the real founder of the experimental study of callus formation is Duhamel (1740), who showed by his classical investigations that the callus is not produced by any particular fluid of the body, but by a formation of bone from the periosteum and marrow.

The size and circumference of a callus varies greatly, according to the condition and position of the broken pieces, the location of the fracture, and the size of the bone. Constitutional conditions also exert an influence. The strongest callus, as a general thing, develops in fractures through the diaphysis of the long bones, which heal with displacement, especially if the fracture has been compound. Considerable disturbance of function may be produced by fractures like these which heal in a position of deformity with such a callus luxurians, as it is called (Fig. 344). The callus is generally slight in flat bones like the scapula or those of the pelvis. After fractures of two parallel bones which lie next one another, as is the case in the forearm, it is possible for a synostosis of the two bones to occur. After fractures in the neighbourhood of joints the callus sometimes extends in the form of processes into the capsule of the joint, or bridges of callus develop, extending from the articular end of one bone to that of the other, and producing anchylosis of the joint. Occasionally true tumours (callus tumours) form from the callus at the point of fracture; these are sometimes benign osteomata, or enchondromata, and sometimes malignant periosteal or myelogenic sarcomata (Haberen).

FIG. 344.—Fracture healed with deformity (callus luxurians).

Effect of Division of the Nerves upon the Callus Formation.—W. Kusmin, experimenting upon the posterior extremities of rabbits, has studied the effect on the callus of dividing the nerves, and he observed that after nerve division the callus is larger and stronger in all its stages than calluses made without neurotomy, and the deposit of lime salts and ossification takes place at an earlier period and more extensively than is the case under normal conditions.

Behaviour of Bone Splinters.—It is of special interest to note what happens to small fragments of bone. Those which remain attached

to the periosteum or bone heal in place the most readily. Smaller splinters are occasionally absorbed. If bone fragments do not become united to the rest of the bone, if they die and remain near the point of fracture, consolidation of the fracture may, in the case of large fragments, be very much delayed, or even entirely prevented, unless the dead portion of bone—the sequestrum, as it is called—is removed (see § 106, Necrosis of Bone). But it has been frequently noted, and even proved experimentally by Ollier, Bergmann, and others, that fragments which have been completely separated from the bone may heal in place perfectly in the case of subcutaneous fractures and of compound fractures in which the wound heals aseptically.

Transplantation of Pieces of Bone into Defects in Bone.—The many experiments with transplantation of portions of bone into defects in bone have an important bearing upon the subject of the behaviour of fragments of bone which have been entirely separated from the bone and periosteum. All the experiments of Ollier, Bergmann, and others show that transplanted portions of bone with or without periosteum heal in place if the wound runs an aseptic course and if no suppuration takes place. Bergmann and Jakimowitsch performed twelve experiments, in ten of which portions of bone twenty millimetres long with and without periosteum and marrow were successfully transplanted; suppuration occurred twice, and in both instances the transplanted pieces of bone failed to unite. Jakimowitsch succeeded in healing a portion of a rabbit's phalanx into the skull of a dog. As a general thing, a loss of bone substance, particularly in the skull, should be repaired by the implantation of a pedunculated flap consisting of bone, periosteum, and soft parts. On the skull the pedunculated skin-periosteum-bone flap is taken from the vicinity of the defect, the surface of the bone being chiselled through, leaving the inner tablet intact. Nussbaum was the first to successfully repair loss of bone substance by pedunculated periosteum-bone flaps, which remained connected to the periosteum by a periosteal bridge at one end of the fragment.

MacEwen successfully repaired a loss of bone substance 11·4 centimetres long in the diaphysis of the humerus by transplantation of small pieces of bone about 0·3 to 0·5 centimetre in diameter. The pieces of bone, including periosteum and marrow, were obtained from osteotomies for rhachitic curvatures in small children. Ollier has successfully repaired losses of bone substance by the transplantation of small hollow bones, such as the first phalanx of the great toe. If the transplantation of bone is to succeed, the strictest asepsis must be employed to prevent suppuration, the extremity must be carefully immobilised, and the transplanted material, including, if possible, the medulla and perios-

teum, should be taken while it is in process of vigorous growth, and consequently from young subjects or newborn children. Gluck has repaired losses of bone substance by pieces of ivory (see § 43), but, as Bergmann found in one instance, the cure was only temporary, and he was obliged to remove the ivory peg on account of the pain and continued uselessness of the hand. Senn and others have successfully employed decalcified bone. In ten cases in which he had good results with pieces of decalcified bone Le Dentu proceeded as follows: He freed the bone to be used, which was generally the femur or tibia of an ox. from periosteum and medulla, decalcified it by immersion for eight days in a sixteen-per-cent. solution of hydrochloric acid; he then washed the pieces of bone, placed them for twenty-four hours in a solution of bichloride of mercury, and stored them in iodoform ether. These implanted decalcified pieces of bone, placed like an internal splint inside the bone, are eventually completely absorbed, but they atimulate the formation of bone. Dead pieces of bone which have not been decalcified and are below a certain size, as proved by the experiments of Ochotin, can be made to heal in place. The dead pieces of bone, like any foreign body, are first surrounded by young connective tissue, and are then permanently enclosed by newly formed bone tissue. Vigorous processes of absorption take place within the encapsulated dead tissue, by which small pieces of bone may be entirely absorbed. The dead piece of bone, as Bergmann has correctly stated, is either encapsulated by bone or its place is taken by living bone tissue. If a large dead piece of bone is made use of for the functions of motion or support, the implanted material does not usually heal in place, and inflammatory (carious) processes take place in the adjoining living bone (Bergmann).

Repair of Fractures of Cartilage.—The process of repair in fractures of cartilage, such as the ossifying costal cartilages or laryngeal cartilages which are covered with perichondrium, is mainly carried on by the perichondrium, and a fibrous cartilage is formed, which then gradually ossifies. Regressive changes usually take place at the broken ends, and the cartilage undergoes fatty degeneration, but at a distance a little further removed from the broken ends of the cartilage there occurs a vigorous proliferation of cartilage cells and a formation of new cartilage tissue (Tizzoni, and others). In cases of interruption of continuity and loss of substance in the cartilage of joints which is not provided with perichondrium, a fibrous connective-tissue cicatrix ordinarily develops, which Tizzoni states is capable in time of changing into hyaline cartilage tissue. Portions of cartilage which have been completely broken off do not regain their attachments, and either become

free bodies in the joint or are encapsulated by new connective tissue formed from the inner surface of the capsule.

The Time required for Fractures to Heal.—The time which is required for the callus formation to reach completion and render the affected bone again capable of performing its function, depends upon the size of the bone which is involved, the nature of the fracture, and not infrequently also upon constitutional conditions. A simple subcutaneous fracture, as a general thing, heals more rapidly than a comminuted or a compound fracture with considerable injury to soft parts. In childhood, healing takes place more rapidly than in adult life. The healing of a fracture may be prolonged by constitutional anomalies, such as the occurrence at the same time of severe acute constitutional infectious diseases, or by syphilis, scurvy, diabetes mellitus, and not infrequently by pregnancy. Gurlt has given the following periods as those required for the healing of simple subcutaneous fractures: A broken phalanx needs about two weeks, the metacarpus, metatarsus and ribs three, the clavicle four, the forearm five, the humerus and fibula six, the neck of the humerus and the tibia seven, both bones of the leg eight, the femur ten, and the neck of the femur twelve weeks before consolidation is complete.

Condition of the Soft Parts and Joints after Healing of a Fracture.—After consolidation of a fracture the full usefulness of the joint is not immediately restored, and the muscles very frequently have become atrophic as a result of their long inactivity. From long-continued immobilisation or too tight dressings this atrophy of the muscles, particularly in anæmic individuals, may give rise to the ischæmic paralyses and contractures mentioned on page 549. Sometimes the functions of the muscles are disturbed by cicatricial shrinkage as a direct result of the injury, or by their insertion having been torn away, or by paralysis in consequence of a complicating injury to the nerves, or from compression of the nerves, for instance, by the callus. The skin very often exhibits slight disturbances of nutrition; it is dry and rough, and the epidermis comes off in scales. Very frequently there are varying degrees of œdema of the skin and subcutaneous soft parts. The rest which the healing of a fracture enjoins also exerts a disadvantageous influence upon the condition of the joints (Menzel, Reyher). In consequence of the shrinkage of the capsule of joints immobilised by the fracture dressing, the joints are more or less stiff after the splint is removed, and sometimes inflammatory effusions occur. Ordinarily, with the increasing use of the joint and under proper treatment (by massage and passive motion) these disturbances very soon disappear. In other cases joint inflammations have their foundation in a

direct injury of the joint, and under these circumstances it is possible for permanent joint disturbances, inflammation giving rise to deformity, anchylosis, etc., to occur (see Diseases of Joints).

Course of the Epiphyseal Separations.—The separations of the epiphyses run essentially the same course as fractures of the bone. We still lack precise anatomical knowledge upon the phenomena of their healing. Great interest attaches to the question of how much disturbance after epiphyseal separations has been observed in the growth of the affected bone on account of ossification of the epiphyseal cartilage. Unfortunately, only a few observations have been recorded on this subject. Bruns's statistics show that a consequent arrest of development only occurs in rare and exceptional instances to any marked degree. Vogt has recorded observations of this kind. In Fig. 345 is represented a shortening of the humerus amounting to twelve and one half centimetres in a thirty-year-old woman which was probably the result of a traumatic separation of the epiphysis sustained in childhood, with subsequent anchylosis of the shoulder joint. Shortening develops especially when the diaphysis and epiphysis are driven into one another and heal together in this position.

Fig. 345.—Impeded growth of the right humerus, probably resulting from a traumatic separation of the epiphysis (Bryant).

Disturbances during the Healing of Fractures.—The most important disturbances which may arise while a fracture is healing are briefly as follows:

1. *Shock.* See § 63.
2. *Delirium Tremens.* See § 64.
3. *Infectious Diseases of Wounds.* See §§ 66–75.—These are particularly liable to occur in the case of compound fractures which have not been treated antiseptically.
4. *Gangrene.* See § 100.—This may be caused by severe injury of the soft parts, by injury to the larger vessels, by pressure of the fragments upon the main artery, by improper treatment, such as too tight dressings, etc.
5. *Necrosis of the Ends of the Fragments.*—This is especially apt to occur in compound fractures when the broken ends lie in the wound

stripped of their periosteum, or when they are badly crushed or splintered into several fragments, or when the periosteum and medulla are to a great extent destroyed by suppuration and sloughing. The dead bone—or sequestrum, as it is called—is then separated from the living bone by a demarcating suppuration (see § 106, Necrosis of Bone).

6. *Fat Emboli.*—Probably in every fracture, as a result of the laceration of the bone marrow and subcutaneous adipose tissue, fluid fat gains access to the blood and lymph vessels which are opened at the point of fracture. Wherever the lumen of the vessels is too small for the passage of the fat drops circulating in the blood at this point, these drops lodge and occlude the vessel. Fat emboli of this kind following fractures are observed particularly in the pulmonary capillaries, and they also frequently occur in the smallest vessels of the brain, kidneys, liver, intestinal villi, etc. As long as the fat emboli are scattered and not extensive their occurrence is entirely unimportant; the fat produces no symptoms worth mentioning of either a local or constitutional nature, beyond causing a temporary occlusionof the lumen of the vessel in question. But sometimes the fat emboli in the lungs or brain are so numerous and so extensive as to cause death, not only in those weakened by age, but now and then in those who are in the prime of life. Death is due to a pronounced accumulation of fat in the capillaries of either the lungs or the brain. Scriba has performed experiments to determine the manner in which fat emboli act, and he maintains that death is mainly the result of their lodgement in the brain. As a rule, death occurs about three to four days after the fracture, and in such cases there is a continual accumulation of fat, during several days, in the capillaries of the lungs and brain, which finally causes a more or less sudden functional incapacity of these organs. It is comparatively seldom that death is the result of fat emboli alone; there are generally other complications.

7. *Embolism of the Pulmonary Artery following Thrombosis of the Larger Veins at the Point of Fracture.*—This serious complication may occur particularly after thrombosis of the deep veins in fractures of the lower extremity. The thrombus in the vein may break loose either while the patient is lying quietly in bed, or because of some movement of the body, from massage, or from a change of the dressing, and death may follow within a few seconds from embolism of the pulmonary artery. König observed death from embolism of the pulmonary artery on the eighteenth day after a subcutaneous fracture of the leg in a strong man thirty years of age. When the patient was laid upon the operating table preparatory to changing the dressings, he was suddenly seized with cramps and opisthotonus, the pupils be-

came dilated, and he died in a few moments. The autopsy revealed a large clot lodged in the pulmonary artery, and it was only with difficulty that the point was found in the vena tibialis antica where the thrombus had originated.

8. *Hæmorrhage.*—In compound and subcutaneous fractures hæmorrhage may occur as a result of the violence which has been brought to bear upon the part, or it may be produced by pointed fragments, splinters of bone, etc. (see §§ 87–89).

9. *Constitutional anomalies* play an important part in respect to the prognosis in the case of any fracture. A fracture sustained by a very old person and entailing a long confinement in bed is a serious accident, for the reason that life may readily become endangered by hypostatic pneumonia.

10. *Delay in the formation of the callus* is particularly apt to occur when constitutional anomalies exist, or in acute and chronic infectious diseases (typhoid fever, syphilis, scurvy), in diabetes mellitus, in diseases of the peripheral nerves and central nervous system, such as progressive paralysis, or during pregnancy, etc.

11. *Pseudarthrosis.*—If bony union does not take place between the fragments, the resulting condition is called a pseudarthrosis—i. e., a false joint (see Fig. 346). In a case of pseudarthrosis, the fragments are either entirely free from connection with one another, or they are joined together by a connective-tissue or cartilaginous intervening substance of varying strength. In rare instances a kind of true joint is observed at the point of fracture—i. e., the ends of the fragments are covered with a layer of hyaline cartilage, and a shallow cavity is hollowed out of one fragment, while the other is rounded to fit it; the periosteum and neighbouring connective tissue surrounds and encloses the broken pieces in the form of a capsule, and in some cases there will be found in the joint-like cavity a fluid which resembles synovia. In pseudarthroses such as this, even synovial villi and loose bodies have been found, the latter sometimes in great numbers.

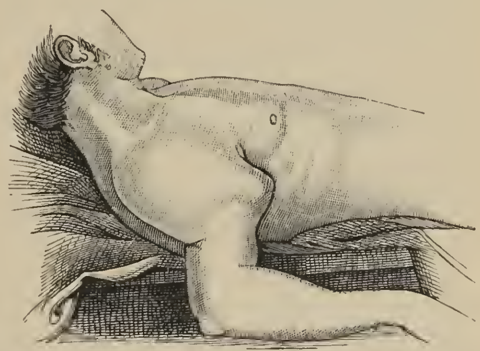


Fig. 346.—Pseudarthrosis of the humerus twelve years old in a fifty-three-old man.

Occurrence of Pseudarthrosis.—In general, pseudarthrosis is not of

common occurrence. Karmilow states that a pseudarthrosis takes place once in about three hundred or four hundred fractures. The pseudarthroses following fracture of the neck of the femur and fracture of the patella are the most frequent. Bruns's statistics seem to show that childhood and old age predispose less to pseudarthrosis than middle life.

Causes of Pseudarthrosis.—The causes of pseudarthrosis are usually local in their nature, being principally those which prevent exact coaptation of the wounded bone surfaces. A pseudarthrosis may result, for example, from a diastasis of the fragments, such as often occurs after transverse fracture of the patella or after loss of a large portion of a bone, owing to its becoming extensively crushed; or the affection may result from displacement of the fragments, or from interposition of muscles, tendons, fascia, foreign bodies (bullets), pieces of dead bone, etc., between the fractured surfaces. In other cases—for instance, after intracapsular fractures of the neck of the femur, or intracapsular fractures of the neck of the humerus—the pseudarthrosis is caused by the insufficient nourishment of one of the fragments. Pseudarthrosis may also originate in consequence of insufficient coaptation of the fractured surfaces due to defective dressings, particularly if the fracture is oblique; under these conditions the fragments are permitted to move and become separated. An influence is sometimes exerted in this direction by a paralysis which may exist at the time of the fracture, or by too little inflammatory reaction in consequence, for example, of the wound healing aseptically in the case of compound fractures. Constitutional disturbances, especially the general weak condition which follows severe febrile diseases, loss of blood, prolonged lactation, pregnancy, etc., have in rare instances given rise to pseudarthroses. Under these circumstances it has also happened that an already ossified callus has softened and been completely absorbed.

The degree of functional disturbance resulting from a pseudarthrosis depends mainly upon the location of the latter, the function of the bone which is involved, and especially upon the amount of motion possessed by the false joint. In a pronounced pseudarthrosis of a long bone, like the femur or humerus, the affected portion of the limb or the entire extremity is quite useless, unless some supporting apparatus is worn.

Diagnosis of Fractures.—The diagnosis of fractures is made from the above-described symptoms. In order to make out the latter, a systematic and careful examination of the injury should be undertaken. This examination consists: 1. In a thorough inspection of the injured portion of the body, noting, for example, changes in its shape and disturb-

ances of function. 2. In palpation of the place where the fracture is presumed to be, combined with passive motion. 3. In an exact measurement of the length of the injured bone, or, rather, the extremity, to determine the presence and amount of shortening. Simple inspection will often be sufficient for the immediate recognition of a fracture. Entirely apart from the crepitation and abnormal mobility, the characteristic linear pain obtained by palpation of the line of fracture will frequently betray the existence of a fracture. In order to palpate the line of fracture more readily, the extravasation at the point of fracture should, when practicable, be removed, or at least diminished in amount, by gentle massage. The corresponding sound portion of the body should always be compared with the injured part, with a view to determining how far the normal position of the constituent parts has been altered by the injury. Not infrequently we have to make the examination during narcosis to find out the exact nature of the fracture, especially when it is compound. In all cases where the diagnosis of fracture is doubtful, the injury should always be treated, for the first at least, according to the rules which govern the treatment of fractures.

Percussion and Auscultation of Bones.—Lücke and Hueter have recommended percussion and auscultation of the bone as an aid in the diagnosis of fractures, particularly when it is desired to determine the presence of fissures in the skull, which can be recognised by the pain the patient feels during the percussion. If soft parts are interposed between the ends of the fragments, Hueter states that auscultation (osteophony) will show a diminution or complete cessation of the conduction of sound.

The Prognosis of Fractures.—The prognosis of subcutaneous fractures without much injury of the surrounding soft parts is, in general, favourable. Transverse fractures heal more rapidly and are less apt to cause lasting deformity than oblique fractures. The location of the fracture is an exceedingly important matter as regards the prognosis. The latter is more favourable in fractures of the extremities than in those of the bones of the skull, trunk, and pelvis, in which the concomitant injuries of neighbouring organs of vital importance, such as the brain, spinal cord, lungs, heart, bladder, etc., may readily give rise to very serious disturbances or death. In other cases injury to a neighbouring large vessel may cause fatal hæmorrhage, or, when the middle meningeal artery is wounded, cerebral compression, with possibly fatal results.

Fractures of the lower extremities in old people, necessitating their confinement to bed for weeks, are always to be looked upon as severe injuries. As a result of the long-continued dorsal decubitus, general disturbances of nutrition, bronchitis, and hypostatic processes in the lungs readily develop, which very often terminate fatally. This fact

is of therapeutic importance, as it teaches us in proper cases to permit patients with fracture of the neck of the femur, for example, to get about on crutches as soon as possible.

The prognosis of fractures involving the articular ends of bones of the extremities is very frequently unfavourable, particularly as regards restoration of the functions of the joint.

The character of the fracture exerts a very important influence upon the prognosis as regards the preservation of the patient's life and the saving of the injured limb, as well as its complete *restitutio ad integrum.* Compound fractures, in particular, are always to be looked upon as severe injuries, and ones which threaten both the limb and life itself, but, thanks to Lister's antiseptic method of treating wounds, we are no longer powerless to combat infectious-wound diseases. In the pre-antiseptic times the mortality of compound fractures amounted to thirty-five to forty per cent., and in especially infected hospitals even to sixty to seventy per cent. and more. Three quarters of the fatal cases were due to septicæmia and pyæmia. At present the mortality of compound fractures, when timely and proper antiseptic treatment is bestowed upon the wound, is extremely small, for the reason that we have learned to prevent infectious-wound diseases. During four years and a half Volkmann cured seventy-five compound fractures without having a single death. From this it is plain that the prognosis of a compound fracture is, in general, more favourable the earlier it is placed under the protection of antiseptic treatment.

Frequently it may be impossible to preserve the broken limb, so that either immediately after the injury, or later, amputation of the extremity must be undertaken.

The extent to which the prognosis of any fracture, subcutaneous as well as compound, may be affected by various accidental circumstances, has been described on pages 589–592.

Treatment of Fractures.—The first aid to the person who has just sustained a fracture often falls to the share of the laity who happen to be present at the accident. Unfortunately, their assistance frequently does more harm than good. In fractures of the upper extremity the patient usually instinctively places the broken limb in a proper position. But the conditions are entirely different in all fractures of the pelvis, vertebræ, and lower extremity, in consequence of which the injured person is unable to walk. Under these conditions the patient must be lifted cautiously after securely supporting the point of fracture. If an individual who has received an injury of this kind has to be transported to his home or to a hospital, the fractured part should be placed in the most secure position possible, a suitable temporary dressing applied to

prevent unnecessary pain and displacement of the ends of the fragments, as well as serious injuries, such as perforation of the skin and severe wounds of the soft parts, particularly of the vessels, with dangerous hæmorrhage, etc. Great care should be used in removing the patient's clothes, portions of the latter—his boots, etc.—when necessary, being slit up with a knife or scissors. The technique of applying an impromptu dressing, the various splints, the arrangement of the bed, the position of the patient, etc., are described in §§ 52–55.

The proper treatment for fractures, particularly those which are subcutaneous, consists in correcting the deformity as soon as possible—i. e., in reposition or reduction of the fragments, and in retention or fixation of the broken pieces after they have been placed in apposition by a suitable retentive dressing until bony union is complete.

Reposition of the Fragments.—The reposition or reduction of the displaced fragments into their normal position is usually brought about by extension (traction) and counter-extension in the longitudinal axis of the broken bone. The extension and counter-extension of the broken limb are usually cautiously performed by two assistants, while the surgeon grasps the point of fracture and brings the fragments into their normal position (coaptation). Manual reposition or reduction will almost always be sufficient. If great force has to be used, or if the pain is intense, narcosis may have to be employed. Extension apparatus, such as the pulley or Schneider-Mennel's frame, which were at one time very much used, have become antiquated. The reduction of many fractures, such as those of the bones of the face or through the condyles in the immediate neighbourhood of a joint, etc., can be accomplished simply by direct manipulation, without extension and counter-extension.

Obstacles to Reduction.—Occasionally various obstacles stand in the way of the successful reduction of a fracture. These include the interposition of splinters of bone or of soft parts between the fragments, impaction of the broken ends in fractures of the articular extremities of bones, and the impossibility of bringing sufficient power to bear upon the fragments. Impaction of the broken ends, such as may occur in fractures of the neck of the femur, should be let alone, for the reason that the impaction favours consolidation of the fracture.

Application of Retentive Dressings.—There are a great number of splints and dressings described in §§ 53–55 for holding the fragments in their normal position after they have been brought into apposition. The ordinary dressing for a fracture is the rapidly hardening retentive appliance made of plaster of Paris (page 216). Extension apparatus are generally used for fractures of the thigh, and can also be employed for the upper extremity (see § 55, page 229), while special splints are

recommended for many fractures, such as those of the lower end of the radius. The hardening retentive dressings should be applied as soon as possible, and it very often happens that subcutaneous fractures will heal under a single dressing. If the swelling at the point of fracture is considerable, ice can be applied to the surface for several days with advantage, and then, after the inflammatory swelling has been reduced, the limb can be placed in the hardening dressing. Even though the swelling is marked the plaster-of-Paris dressing can be immediately applied, if the parts are first carefully padded with cotton. In such cases the hardening dressing has an antiphlogistic effect from its gentle and even pressure—i. e., it prevents an increase in the swelling. After a certain length of time this dressing becomes loose and does not sufficiently immobilise the point of fracture, and hence it must be taken off and replaced by a new one. In putting on the hardening dressing great care must be taken not to apply it too tightly. Subseqnently the fingers and toes should be carefully watched, and if they swell or become bluish-red or œdematous, if pain or a feeling of numbness occur, the bandage has been applied too tightly and must be immediately removed. Every plaster-of-Paris dressing, whenever it is possible, should be again carefully inspected some hours afterwards to determine whether it has not been applied too tightly. Incurable ischæmic muscular contractures may readily develop within a few hours after the application of a plaster-of-Paris dressing which is too tight (see page 549), and for these the attending physician can be held legally responsible.

A warning should be given against the too prolonged use of retentive dressings and the rest in bed which this entails, because of the bad effect produced upon the general health, the atrophy of the muscles, the enforced disuse of the joints, etc. On account of these serious possibilities, and particularly on account of the danger of hypostasis, old people with fractures of the lower extremities must often be allowed to leave their bed and go about on crutches with a suitable splint, and with a raised sole on the shoe of the sound leg. Recently successful results have been obtained by allowing all patients with fractures to walk about with suitable splint dressings, and by avoiding, for the above-mentioned reasons, the treatment with dressings which require a long confinement to bed. Within five to seven days the patients are allowed to move around on crutches in a proper retentive apparatus, such as a Thomas splint, with a raised sole under the foot of the sound side (see second edition Special Surgery, vol. ii, Fig. 723, p. 623). The results are very satisfactory, and the time required for healing to be accomplished is shortened.

Treatment of Subcutaneous Fractures involving a Joint.—In sub-

cutaneous fractures involving a joint special care must be taken to prevent the development of anchylosis or a partially stiff joint (contractures). This is best accomplished by the use of suitable splints or a plaster-of-Paris dressing, which should be frequently changed—every five to eight days, for example—and reapplied after altering the position of the joint. Massage and passive motion may be combined with this—for example, at every change of dressing. Extension appliances are also very useful, and may be employed, as Bardenheuer has recently recommended, even for fractures of the upper extremity which involve joints. If it is difficult to maintain the fragments in position after they have been reduced, they may be fastened together by aseptic steel nails or pins (see page 111).

Treatment of Traumatic Separation of the Epiphysis.—For securing bony union after traumatic separations of the epiphyses, the fragments should be directly united by long aseptic steel nails or pins (Trendelenburg, Bruns, etc.). Helferich has recommended long steel pins attached to a removable handle, by which they can be slowly screwed into a bone; they can be used for both subcutaneous and compound epiphyseal separations.

Direct Fixation of the Fragments in Subcutaneous and Open (Compound) Fractures, Suturing, Nailing, etc.—In all subcutaneous or compound fractures, where it is difficult to maintain the fragments in proper position, the wounded bone surfaces can be held in contact by directly suturing them together, by driving nails into them, or ivory pegs, or Helferich's steel pins, or by placing bone or ivory pegs in the medullary cavity, as described in § 34 (Union of Wounded Bone Surfaces). In this category belong Malgaigne's hooks for fracture of the patella and Malgaigne's pin for fracture of the tibia—instruments which are scarcely ever used at present. If nails are to be used to secure fixation of the bones, long four-cornered steel ones should be employed. These are polished, boiled for fifteen minutes in a one-per-cent. soda solution, heated red-hot, and placed in a ten-per-cent. solution of carbolic acid in glycerine, after which they are perfectly sterile. After the bones have been nailed together they are securely immobilised. The wounds in compound fractures are not sutured, but packed with sterilised gauze. The nails are removed about the beginning of the fourth week.

The Treatment of Open (Compound) Fractures.—The treatment of open (compound) fractures has been totally changed by the antiseptic method of treating wounds, and the results which we now obtain are very satisfactory. Typical cases of compound fracture which run an aseptic course heal without pain and without fever; the discharge from

the wound is slight, and we are certain of being able to prevent suppuration.

The technique of the antiseptic treatment of the wound varies with the kind of case. For this reason we distinguish three classes of cases: 1. The perfectly fresh fractures in which the wound is the result of a perforation of the skin by a fragment. 2. The ordinary severe cases of compound fracture. 3. The compound fractures which are not recent and have already become infected.

1. **Treatment of Fresh Fractures with Transfixion of the Skin by a Fragment.**—The antiseptic management of a perfectly fresh fracture complicated with a perforation of the skin by a fragment is as follows: We will suppose that we have to deal with a fracture accompanied by only a small, still bleeding cutaneous wound, similar to a punctured wound; that the case comes under observation immediately or within a few hours after the reception of the injury; that there is no large extravasation of blood present; that the bone is simply broken, and not splintered; and that no infectious-wound disease can be made out. In such cases enlargement of the wound and drainage can be omitted. After disinfection of the wound and surrounding parts, as described in § 6 and § 32, the wound is covered with an antiseptic dressing, such as sterilised gauze, folded together into several layers, and cotton, wool, or pads filled with moss. Should the wound have become closed by a dried blood-clot and no indications of infection be present, this scab can be left undisturbed and the fracture allowed to heal under it. A plaster-of-Paris dressing can then be immediately applied over the antiseptic dressing. This antiseptic plaster-of-Paris occlusive dressing is left in place, if no fever or pain in the wound occurs, for two or three weeks longer, until the wound has healed, and is then, if necessary, replaced by a simple plaster-of-Paris dressing until complete consolidation of the fracture has taken place. This antiseptic plaster-of-Paris occlusive dressing has been recently very much employed for fresh compound fractures with small wounds, and also in the treatment following osteotomies of the rhachitic extremities of children. Bergmann, Reyher and others obtained brilliant results in the Turko-Russian War with this same form of dressing, even in such injuries as gunshot wounds of the knee. The method is not suitable for severe compound fractures with extensive wounds of the soft parts, nor for cases which are not perfectly fresh when they come for treatment.

The opinions of surgeons still differ as to whether the antiseptic occlusion carried out in the manner above described should likewise be used for fresh comminuted fractures with a small cutaneous wound, or whether the wound should be enlarged and the splinters extracted.

At all events, the brilliant results obtained by Bergmann and Reyher in the Turko-Russian War show that the primary extraction of the fragments, formerly so much insisted upon in comminuted fractures, is not always necessary; that the above-described simple antiseptic occlusion, without enlarging the wound and without extraction of the fragments, gives even here excellent results; and that the splinters, though very numerous, are capable of healing up completely in the wound, provided the wound runs an antiseptic course.

2. **The Antiseptic Management of Severe Compound Fractures,** with extensive injury to the soft parts, likewise consists in a thorough disinfection of every portion of the wounded surface and of the surrounding parts to a considerable distance from the wound. If the opening into the wound is not large enough to permit of careful examination or disinfection of the entire wound cavity, it should be enlarged with the knife, using for the extremities Esmarch's artificial ischæmia. The point of fracture is inspected, and the entire cavity of the wound is energetically irrigated with a one-tenth-per-cent. solution of bichloride of mercury, crushed shreds of tissue are cut off with the scissors and forceps, the hæmorrhage carefully arrested, foreign bodies, bullets, etc., are removed, and long, deep pockets under the skin or deeper parts are split open. If necessary, the fragments may be drawn out of the wound with sharp hooks or bone forceps, to render it possible to systematically examine and disinfect them and the soft parts lying behind them. Counter-openings are made for the admission of short, large-sized drainage tubes to the most deeply lying parts, and every niche, every recess in the wound, and every pocket, should be carefully drained or split open. The deep drains should always extend to the cleft in the bone, but should not lie between the fragments. Tamponing the wound with iodoform gauze or sterilised mull supplies excellent drainage. If splinters are present, all those which are entirely loose and dead should be removed, while those, on the other hand, which are still alive and attached to the periosteum should be retained, and, if displaced, returned to their normal position. Projecting points on the fragments which interfere with reduction should be removed with the bone forceps or saw. If it is difficult to maintain the fragments in position after their reduction, they may be secured in their normal situation by sutures through the ends of the bone, or by nailing them together aseptically (see page 597).

After the wound, with all its recesses, has been very carefully disinfected and drained, we proceed to insert the sutures, provided the case is one suited for primary union. I believe it is wiser not to suture wounds of this kind, but to leave them open and pack them with iodo-

form gauze or sterilised mull, over which is placed an antiseptic protective dressing.

Resection of the Broken Ends.—Formerly, in the case of compound comminuted fractures of the long hollow bones, the splintered ends of the bone were frequently removed (so-called resection in continuity). This primary resection immediately after the injury is only applicable for the most severe cases. If, during the subsequent course of compound comminuted fractures, necrosis of the broken ends takes place, then secondary resection of the fragments is indicated to obtain more rapid healing.

Treatment of Compound Fractures of Joints.—If we have to deal with a compound fracture of a joint, we proceed according to the same principles—i. e., the joint is exposed by a sufficiently long incision, carefully disinfected, and drainage provided for. When necessary, we also remove any crushed fragments of bone, extract the free splinters, or, in the severest cases, perform total resection of the articular ends of the bones. Speaking generally, resection in compound fractures of a joint is governed by the following principles (see § 40): Primary resection is indicated in fresh, non-infected, extensive comminuted fractures of the articular ends of the bones, accompanied by great injury to the soft parts. Compound fractures involving a joint with only a small cutaneous wound, after careful disinfection of the latter, should be treated at first as though the fracture were subcutaneous. If the attempt fails, and inflammation or suppuration of the joint with fever comes on, then arthrotomy should be performed—i. e., the joint is opened freely, the fracture exposed, carefully disinfected, and drained. Not infrequently, under these conditions, fixation of the fragments by sutures or nails renders excellent service. Whether a typical resection of the broken articular extremities should be performed depends upon the character and severity of the injury to the bone and the extent of suppuration or infection. At all events, resection is indicated when fever and local inflammation continue after arthrotomy and drainage of the joint, and when there is a probability of a severe infection of the wound of the bone having taken place.

Subsequent Treatment of Compound Fractures.—The rest of the treatment of compound fractures depends upon their subsequent behaviour. In the most favourable cases, running a course free from fever, the first dressing is left in place six to eight to ten to fourteen days and then changed, and at the same time any drains, sutures, or tampons are removed. If, on the other hand, fever should occur, or the patient complain of pain in the wound, the dressing should be immediately changed and the wound and parts surrounding it carefully examined

for the presence of retained discharges, which should be immediately let out by an incision. The granulating wound should also be treated strictly according to antiseptic principles, and a closed or fenestrated plaster splint, or one of the modifications given under § 54, applied until the wound has become covered with skin. We cover large granulating surfaces with skin by Thiersch's method of skin grafting. When the wound has healed, a closed plaster splint is applied, if necessary, until consolidation of the fracture is complete.

3. **Treatment of Fractures which are not Fresh and have become Septic.**—We count all cases as not "fresh" which come under observation twenty-four to forty-eight hours after the injury, with already existing local inflammatory changes in the wound. Of course, the character of these cases varies greatly, according to the severity and nature of the reaction which is present in the wound. If the reaction in the wound is slight, an aseptic course of repair may not infrequently be obtained by energetically disinfecting, enlarging, and draining the wound and then applying an antiseptic occlusive dressing. Tamponing the cavity of the wound with iodoform gauze or sterilised mull, and omitting all sutures, is a procedure particularly applicable for such cases.

In other instances, again, the reaction in the wound will have already become very marked. There is pronounced decomposition and putrefaction of the discharges, and the crushed soft parts and cellular tissue are gangrenous, and saturated with the products of decomposition. The suppuration and putrefaction which are present are no longer limited to the wound, but have begun to spread progressively. Not infrequently there is such a large accumulation of putrefactive gases that a pronounced gaseous infiltration (emphysema) takes place. Even in such unfavourable cases of pronounced sepsis a vigorous disinfection of all the septic tissues should be undertaken and incisions made in great numbers. We, of course, avoid applying the ordinary closed protective dressings which exert pressure, and content ourselves with energetic disinfection of the wound, covering it with sterilised gauze or iodoform gauze, or employing permanent antiseptic irrigation (see page 178). As long as the treatment lasts it is exceedingly important to keep the extremity in an elevated position and the fragments as securely immobilised as possible. When the wound has become aseptic and is granulating, we cover it with iodoform gauze and cotton and immobilise the fragments by a suitable splint, or by a fenestrated or interrupted plaster-of-Paris dressing. The treatment of compound fractures which have become infected demands much patience and care, and, above all, experience. It is very important to note the be-

haviour of the temperature by means of the constant use of the thermometer, and to recognise any retention of discharges at the earliest possible moment and to let them out by incisions.

Indications for Amputation and Disarticulation.—In which cases of compound fracture should amputation or disarticulation of the injured limb be performed? Immediate amputation or disarticulation of the injured limb directly after the reception of the injury, or within the first twenty-four to forty-eight hours, before the reaction in the wound sets in, is only indicated in cases of very severe crushing of the bone with extensive injury to the soft parts (primary amputation). With the aid of the antiseptic method of treating wounds we are enabled to carry out conservative treatment successfully in cases where formerly preservation of the injured limb would have been impossible. The opening of a large joint or injury of large arteries and nerves do not in themselves indicate primary amputation, though it should be immediately performed if the soft parts, muscles, vessels and nerves are so extensively lacerated and crushed that preservation of the limb is impossible or gangrene is sure to follow. The decision as to whether amputation should be immediately performed or not is not always easy. After having determined upon amputation, we perform it through sound tissues which have not been crushed, and take the greatest care to avoid fashioning the flaps which are to cover the amputation wound, from the contused portions of skin or those portions that have been torn loose from the underlying parts.

Amputation is also indicated in the case of many infected compound fractures when the local wound infection, the suppuration, putrefaction, etc., have become so extensive as to render preservation of the limb impossible, or when severe manifestations of general septic infection make their appearance. In such cases we amputate—in other words, we remove the source of infection in order to save the life of the patient. Delay in such cases is dangerous, and the sooner amputation is performed in the presence of high, septic fever, the better is the prospect of recovery. In the later stages of compound fractures amputation is indicated, especially when there is extensive suppurative inflammation of the medulla of the bone or of the joints, or when the patient is in danger of exhaustion from severe suppuration, etc. Briefly speaking, we amputate when the condition of the extremity is such that healing cannot be expected from conservative treatment.

After-treatment of Fractures.—The after-treatment is directed principally towards the joints and the disturbances in nutrition which occur in the soft parts, particularly the skin and muscles. Very often no special after-treatment is necessary when consolidation of the fracture is completed. Massage, diligent exercise of the muscles, and active and passive motion of the joints will usually soon remedy the muscular weakness and the stiffness of the joints, and the sooner these measures are adopted the better. A warning should be given against the too protracted use of retentive dressings for fractures, on account of the atrophy of the muscles and the disturbances in the functions of the

joints which they cause. In the case of old people particularly it is often necessary to give up the confinement to bed because of the threatening hypostasis or disturbance of the general health, and to permit them to move about, even with fractures of the lower extremity, on crutches, and with suitable splints and a raised sole under the foot of the sound leg (see page 596). In proper cases, such as in fractures of the radius with the ulna intact, or of the fibula with the tibia intact, massage can be begun at a very early period—within the first or second week, for instance—and a more rapid recovery will thus be obtained. Of course, the above-mentioned fractures must be immobilised a long enough time—two to three weeks at least—by proper splints. Baths and rubbing with alcohol are also of use. If there is much œdema, particularly, for example, in the case of the lower extremity, the latter should be enveloped in a tight flannel bandage, or retentive dressings which can be readily removed should be applied (Figs. 201, 205). If a long time has elapsed since consolidation of a fracture in the extremities, and if the stiffness of the joints and atrophy of the muscles, owing to lack of energy on the part of the patient or physician, has become very pronounced, it is all the more difficult to restore the normal function. In such cases it is sometimes best to repeatedly anæsthetise the patients for the purpose of moving the joints and performing vigorous massage. It is in just these cases that massage not infrequently yields most brilliant results. In these old cases, where motion is impaired and there are contractures and muscular atrophy, methodical exercises by means of the mechanical appliances in the orthopædic institutes are exceedingly valuable. If we have to deal with ischæmic contractures and paralyses, they should be treated according to the rules mentioned on page 550.

Treatment of the Complications.—The treatment of the above-mentioned complications is described in previous paragraphs — shock in § 63, delirium tremens in § 64, infectious diseases of wounds in §§ 66–75, and gangrene in § 100, etc.

Treatment of Delayed Callus Formation and Pseudarthrosis.—For these conditions the following methods are particularly valuable: 1. Rubbing together the ends of the bones (Celsus), according to Karmilow, was successful only forty times in four hundred and thirty cases. In this method, which is suited more for cases with delayed callus formation, the fragments are rubbed together daily until a sufficient local reaction has set in and the point of fracture is tender on pressure. A plaster-of-Paris dressing is then applied. Patients with fracture of the lower extremity can be allowed to move about in a retentive dressing for the purpose of maintaining an inflammatory irritation at the point

of fracture. 2. Artificial increase of bone formation by the production of a venous hyperæmia at the point of fracture by tying off the extremity on the proximal side of the fracture with a rubber tourniquet drawn moderately tight. In order that the hyperæmia may be localised at the point of fracture the extremity above and below it can be enveloped in a bandage (Dumreicher, Helferich, etc.). The procedure can be combined with the application of a plaster or other kind of splint, and it is here also a good plan to permit patients with fracture of the lower extremity to move about in a proper dressing. 3. Le Fort has successfully employed electrolysis—i. e., two platinum needles connected with a constant battery are stuck into the false joint. The needle fastened to the positive pole is kept in one place, while that fastened to the negative pole is introduced repeatedly at several different points. 4. The employment of various other means of irritation has been abandoned (irritation of the skin, subcutaneous injections of irritating chemical liquids, etc.). Nevertheless, Mikulicz has used oil of turpentine with excellent results. After making a longitudinal incision through the soft parts and periosteum, the latter is freed from almost the entire circumference of the bone with the raspatory to a distance of about ten centimetres from the point of fracture, and gauze saturated with oil of turpentine is placed between the bone and periosteum and changed every three to five days until the wound has healed. As yet, Bergmann has seen no case of pseudarthrosis cured by the oil-of-turpentine treatment. 5. Irritation of the ends of the bones by driving ivory pegs into them (Dieffenbach) is performed in the following manner: After the soft parts above and below the point of fracture have been divided with the knife, holes are bored in the bone with a drill, and one or two ivory pegs, according to the size of the bone, are driven into each fragment. The extremity is then encased in a plaster dressing, which may be fenestrated or not. The ivory pegs are allowed to remain two to three weeks or longer. Karmilow states that the procedure when applied to the thigh and arm has been successful in 43·5 per cent. of the cases, while for the leg and forearm the number of cures have amounted to eighty per cent. Instead of ivory pegs, Riedinger has recommended bone pegs, which are capable of becoming firmly adherent to the bones.

If the procedures hitherto described do not prove successful, there is nothing left but to expose the false joint with the knife, to freshen the ends of the bones, to resect them, and then, when necessary, to fasten them together by sutures of catgut, sterilised silver wire, iron wire, or silkworm gut, or by nails. The ends of the bones can be freshened by resecting them in the form of steps and thus fitting

them together; or the pointed end of one fragment can be introduced into the medullary cavity of the other (see page 111, Fig. 94). Exposure of the false joint, followed by freshening the ends of the bones and uniting them with sutures or nails, is the safest method of treating all false joints of long standing, and if carried out with antiseptic precautions it is entirely free from danger. For nailing the bones, we use, as was said before, long, four-cornered steel nails, which are rendered perfectly sterile by polishing, boiling for fifteen minutes in a one-per-cent. soda solution, heating red-hot, and storing in a ten-per-cent. solution of carbolic acid in glycerine. After nailing the bones together, an antiseptic protective dressing is placed over the wound, which is left open, and a gypsum dressing is applied on the outside. The nails are removed at the end of the third or beginning of the fourth week.

Treatment of Losses of Bone Substance—Transplantation of Bone.—If a considerable loss of substance has occurred in one of the two bones of the forearm or leg, we may either chisel out of the other bone a piece corresponding in size to the defect, and cause the ends of the bones to unite, with a corresponding amount of shortening, or we may adopt Nussbaum's plan, and, after freshening the ends of the bone, fill up the defect caused by the loss of substance with one or two pedunculated bone-periosteal flaps. In proper cases, as, for example, on the skull, a loss of bone substance is repaired by pedunculated skin-bone flaps taken from the vicinity of the defect, the bone being cut from the outer tablet (see Special Surgery). We can also transplant into the defect, as MacEwen, Ollier, Bergmann, and others do, several free pieces of bone, from 0·3 centimetre to 0·5 centimetre in length, retaining their periosteum and medulla; or we can use for this purpose a small hollow bone like the first phalanx of the great toe, as described on page 586. The bone material used for transplantation must be taken while it is still undergoing active growth, and, consequently, from young subjects or newborn infants, and suppuration must be prevented by the strictest asepsis. Losses of bone substance have also been successfully repaired by pieces of decalcified bone (see pages 586, 587, Transplantation of Bone). In one case where there was a loss of substance in the tibia, Hahn successfully implanted the fibula into the tibia.

The internal administration of lime, or, what is better, of phosphorus (Wegner), has been recommended for pseudarthrosis. Any constitutional or local anomaly which may be present must always, of course, be taken into consideration.

If all methods of treatment prove unsuccessful, care must be taken

to alleviate the disturbance of function, as far as possible, by a suitable splint apparatus. If the peripheral portion of the limb has become so atrophic and flail-like as to render the wearing of a supporting appliance scarcely possible, amputation, particularly if it is the lower extremity which is involved, is indicated.

The Erosion of an Ivory Peg which has been driven into a Bone.—It is well known that ivory pegs which have been driven into a bone become roughened and appear as though portions of their surface had been gnawed away (Fig. 347). Polynuclear giant cells are found in the small cavities, and the same osteoclasts which are present during the normal process of bone absorption. The cause of this lacunar-bone absorption is partly to be ascribed to the action of an acid and partly to the pressure of the vessels and the cells of the surrounding tissues. I have shown that it is probably the carbonic acid which, *in statu nascendi*, during the metabolism of the tissues, sets free the lime in the ivory peg, and that then the decalcified ground substance which is left behind is dissolved by the alkaline fluids in the tissues (see page 583).

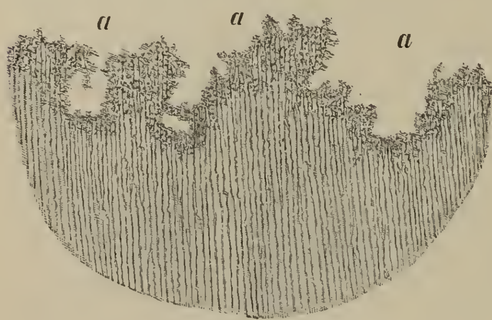


Fig. 347.—Erosion (*a*) of an ivory peg by the action of carbonic acid.

The Treatment of Fractures which have healed with Deformity.—Deformity in the healing of a fracture should be prevented by careful supervision of the point of fracture, or, in other words, of the position of the fragments while the process of healing is going on. The retentive dressing should be changed too often rather than too infrequently. If a fracture heals with so marked a displacement as to produce serious disturbance of function, the bones should either be refractured or the point of fracture exposed, chiselled through, and the ends of the bones then reunited in a good position. Those cases, as a general thing, are least amenable to treatment which have healed with considerable *dislocatio ad longitudinem*. The bones are broken under chloroform anæsthesia either by hand or by some special apparatus. The machines used for directly fracturing the bones are called osteoclasts; the ones invented by Rizzoli and by Collin and Robin are very useful (see page 84). The open division of fractures which have healed with deformity is carried out by making an incision through the soft parts, thus exposing the point of fracture, and then dividing the bone with the hammer and chisel (osteotomy). The bone is not chiselled entirely through.

but a small portion is left, which is broken by hand. When necessary, a wedge-shaped piece must be chiselled out of the deformed bone. Osteotomy of the bone is absolutely free from danger if the rules of asepsis are carefully observed. The wound is not sutured, but left open and packed with sterilised gauze, and directly over the protective dressing a plaster splint is applied, which is left in place until the wound has healed, though it is changed earlier if there is need of doing so. In cases of considerable shortening from mal-union of a fracture, the use of extension by a weight, after performing osteotomy, is very much to be recommended. Badly united fractures, of the femur for instance, occurring in adults and accompanied by much shortening, sometimes require powerful extension (by a weight amounting to twenty to twenty-five to thirty pounds), and surprisingly good results may be obtained, as both Schede and myself have observed. Under certain circumstances Schede recommends increasing the weight used for extension in the case of adults to as much as forty pounds.

Moritz and Meyer have used the electric current with success for exuberant callus (callus luxurians).

§ 102. **Contusions and Wounds of Bone.**—If a bone is crushed by a blow from a blunt object, we have especially to consider, in addition to the contusion of the bone substance, the injury to the overlying soft parts, the skin, the subcutaneous cellular tissue, and the periosteum. The course of contusions of the soft parts is described in § 92. Contusions of periosteum lead to a greater or less extravasation of blood into and particularly beneath the periosteum, which is called a hæmatoma of the periosteum. These periosteal and subperiosteal extravasations of blood usually terminate by being gradually absorbed. Not infrequently there develops, at the point where the periosteum has been contused, a traumatic, ossifying periostitis, in consequence of which the bone becomes only temporarily thickened.

The anatomical changes which occur in contusions of bone tissue proper consist in a more or less pronounced compression or splintering of the bone substance, such as happens after a thrust or blow, and to a marked degree in every fracture. In the medullary cavity an extravasation of blood is found proportionate in size to the amount of violence exhibited. As is the case with fractures, the course of contusions of the periosteum, bone, and medullary tissue depends mainly upon whether an external wound is present or not. Only in the most exceptional instances of subcutaneous contusions of bone do inflammatory or suppurative processes occur, and when they do, it is owing to the deposit of micro-organisms from the blood in the contused portions of bone and medullary tissue, or to the extension to the deeper parts of

inflammatory processes existing in the contused skin. Primary acute infectious osteomyelitis is probably sometimes caused by such a contusion of the medullary and cortical tissue. It is a well-known fact that tuberculosis may originate from some slight contusion of the bone, particularly in the case of children, for the reason that the tubercle bacillus finds in contused tissues and extravasations of blood conditions which are favourable to its development. The vascular arrangement in the medulla is such that solid impurities in the blood readily become deposited. The inflammation of bone to which mother-of-pearl turners are subject is an instance of this (see page 618).

The treatment of subcutaneous contusions of periosteum and bone consists at first in placing the injured part in a suitable (elevated) position, in the application of ice, and later in employing massage to promote absorption of the blood extravasated in the periosteum and soft parts. Inflammatory complications, suppuration, etc., are treated according to the general rules laid down in §§ 68–71.

Open Wounds of Bone.—The open wounds of bone have lost the danger that used to attend them before the introduction of the antiseptic method of treating wounds. By the latter means all infection is avoided, and even deep wounds which penetrate into the medullary cavity heal without complications. The most common wounds of bone are those occurring in fractures. True wounds of bone are such as are caused by a blow, or a thrust with a sabre, knife, axe, etc. In consequence of this violence there may be produced in the skull for example, the fissures or cracks, mentioned under Incomplete Fractures, which divide the bone either partially or completely. On the extremities, particularly the fingers, complete division of the bone and soft parts is frequently observed. Now and then, by paying strict attention to antisepsis, phalanges or finger tips which have been entirely severed may be sutured in place and caused to reunite. Careful subcutaneous suturing of the periosteum with catgut and absolute immobilisation of the affected part are of chief importance. I once saw a terminal phalanx which had reunited in this way come off again four weeks later in consequence of a violent blow, and then it could not be made to heal on a second time. If a piece has been taken out of the continuity of a bone by a sabre cut, for example, and there is no periosteum left at the spot in question, the bone will granulate very soon, and skin will gradually form over the granulating surface. Very often the loss of substance in a bone of the skull is not completely replaced by new bone, and persists as a more or less appreciable gap.

The repair of a wound in bone is essentially the same as that which takes place in fractures, and is described on page 580. Gunshot wounds

of bone and soft parts will be discussed in conjunction with injuries of joints (see § 124).

§ 103. **The Inflammations of Bone.**—The inflammations of bone generally begin in the periosteum and in the medulla in the form of a periostitis and osteomyelitis. From these regions the inflammation extends to the bone substance proper and to the epiphyseal or articular cartilages, giving rise to a true ostitis or chondritis. The ostitis manifests itself either as an absorption of bone (rarefying ostitis) or as a new formation of bone (condensing ostitis). The inflammatory changes in the bone proper take place in the parts surrounding the vessels and in the medullary spaces. The pathological absorption of bone is, as a rule, analogous to the normal absorption—i. e., it takes place in the form of pit-like depressions, the so-called Howship's lacunæ (lacunar absorption of bone), which are hollowed out of the bone by the action of polynuclear cells—the osteoclasts, as they are called (Kölliker, Fig. 343). In this lacunar absorption of bone the lime salts and the ground substances are always dissolved more or less simultaneously. In a second form of absorption of bone—in halisteresis ossium—the lime salts become at first dissolved, the decalcified ground substance of the bone persisting for some time longer. The latter kind of absorption of bone takes place especially in osteomalacia (see § 109). The changes which occur in inflammation of cartilage consist mainly in a proliferation of the cartilage cells and in a fibrillary degeneration and necrosis of the ground substance of the cartilage.

§ 104. **Acute Inflammations of Bone, Acute Periostitis, and Acute Osteomyelitis.**—The acute inflammations of bone, in the form of an acute inflammation of the periosteum and medulla (acute periostitis and acute osteomyelitis), have been studied in their simplest form in § 101, under the subject of Callus Formation after subcutaneous fractures. In every instance where a suppurative periostitis and osteomyelitis occurs it is due, like any acute suppuration, to infection by micro-organisms. The infection has either taken place at the point where the injury was received, as in the case of compound fractures which are not treated antiseptically and open wounds of the periosteum, or it has spread from a suppurative inflammation of the surrounding parts, or, thirdly, it originates by infectious matter being brought from another portion of the body by the blood-vessels and deposited in the bone (hæmatogenous infection). The latter kind includes the metastatic inflammations of the periosteum and medulla occurring in pyæmia, typhoid and scarlet fevers, etc. Such acute inflammations of the periosteum and medulla not only develop in the course of acute infectious diseases from metastasis of their poisons, but

also occur in perfectly healthy individuals, and are due to micro-organisms which are carried to the bone in the blood from the external cutaneous covering, the intestinal tract, the lungs, etc., and there excite the various kinds of inflammation.

Acute Infectious Osteomyelitis.—The severest acute inflammation of bone is the primary acute infectious osteomyelitis and periostitis (Lücke) first described by Chassaignac as *osteomyelite spontanée diffuse des os* or *typhus des os* or *des membres.* This is chiefly observed in young people. Young growing bones, as a general thing, possess a more or less pronounced tendency towards inflammatory processes. An active development of new vessels takes place in growing bone, and the terminal loops of the vessels with their dilatations lie close to the epiphyseal cartilage; consequently solid impurities, especially micro-organisms, can be deposited in the cartilage from the retarded blood stream. Moreover, the filtration and deposition of micro-organisms and all solid impurities contained in the blood is rendered easy in the medulla of every bone, for the reason that the blood stream is not confined by walls as it passes through the sacculated medullary spaces. Osteomyelitis occurs most commonly in the femur of young subjects, possibly because this bone grows the most rapidly. According to Haaga's statistics, covering forty years' experience in the clinic at Tübingen, the disease occurs more frequently in men than in women, the proportion being 3·38 to 1. Acute osteomyelitis is particularly common in certain regions, such as Switzerland, the mountainous parts of South Germany, and the coast of North Germany. Epidemics of very severe cases occur in these places. In other instances acute osteomyelitis is secondary, and occurs, for example, in the course of acute infectious diseases such as measles, scarlet fever, small-pox, or typhoid fever (see page 617). We shall confine ourselves at present mainly to the primary acute osteomyelitis.

Etiology of Primary Acute Osteomyelitis.—Our knowledge of the etiology of primary acute infectious osteomyelitis has recently been advanced, particularly by Kocher, Rosenbach, Kraske, and others. It has been found that in the majority of cases it is caused by the yellow pus coccus, the staphylococcus pyogenes aureus, less often by the staphylococcus pyogenes albus (see pages 321–325). Occasionally there is a mixed infection—i. e., in addition to the staphylococcus pyogenes aureus other pus cocci will be present, especially the staphylococcus pyogenes albus or the streptococcus pyogenes. In fifteen cases of acute osteomyelitis, Rosenbach found the staphylococcus pyogenes aureus fourteen times, once with the chain coccus of cellulitis, and once with the white pus coccus (staphylococcus pyogenes albus). In only one case of osteomyelitis was the yellow coccus absent, and in this the white coccus alone was found. In nine cases out of twelve Colzi found only the staphylococcus pyogenes aureus, and in three instances the staphylococcus albus was

also present. In forty-five cases of osteomyelitis, Lannelongue and Achard found the staphylococcus pyogenes albus twenty-eight times, the staphylococcus albus seven times, the staphylococcus aureus and albus together once, the staphylococcus citreus once, the streptococcus four times, the pneumococcus twice, and twice a micro-organism which could not be positively identified (pneumococcus [?]). The staphylococcus pyogenes aureus, and particularly the streptococcus pyogenes, are more virulent than the staphylococcus pyogenes albus. Osteomyelitis can also be produced by the intravenous injection of the bacterium which produces lactic acid, by typhoid bacilli, pneumococci, etc. Like any other acute inflammation and suppuration, osteomyelitis can be excited experimentally in animals by agents having a purely chemical action, such as turpentine or sterilised cultures, the latter producing their effect through the chemical products resulting from the metabolism of the pus cocci (Ullmann). In short, osteomyelitis can be excited by many varieties of micro-organisms and chemical agents, but the ordinary pus cocci are the most common cause of the disease. Consequently osteomyelitis is not due to a specific poison, as was believed to be the case for a long time, but it may be caused by any kind of micro-organism which excites acute inflammation and suppuration. Acute infectious osteomyelitis is essentially a phlegmon, so to speak, of the medullary cavity. By transferring osteomyelitic pus, or the above-mentioned micro-organisms, to the soft parts, a cellulitic inflammation and suppuration is produced. The experiments of Becker and others show that after the introduction of pus cocci into the circulatory system or peritoneal cavity, typical acute osteomyelitis is particularly likely to develop if the affected bones have been previously contused or broken, for the reason that broken or contused bone offers a favourable medium for the growth of the pus cocci.

As Kocher first stated, the origin of acute infectious osteomyelitis is to be explained on the supposition that the above-mentioned micro-organisms enter the circulation from some point in the skin, or in the lungs or intestinal tract, for example, particularly when at this point there is an inflammation, such as a furuncle, or even a slight interruption of continuity, and are carried off in the blood, from which they are deposited in the medullary portion of the bones of youthful subjects for the anatomical reasons mentioned before; here they develop, and give rise to severe suppurative or gangrenous inflammation with secondary involvement of the bone, periosteum, and frequently the joints. Colzi's experiments seem to show that the bacteria in osteomyelitis enter the body most frequently from the skin, less often from the lungs or intestinal tract. Inflammations of other organs, such as the spontaneous acute inflammation of the thyroid gland occurring in rapidly growing goître, originate in a similar way from infection through the blood (Kocher). As we remarked before, traumatic lesions of bone favour the development of acute infectious osteomyelitis. How far catching cold conduces to its occurrence is a matter which cannot be determined, but the majority of surgeons believe that it exerts some influence. Acute infectious osteomyelitis is also occasionally observed as one of the sequelæ of acute infectious diseases (measles, scarlet fever, typhoid fever, diphtheria), and may follow suppurative inflammation of various organs. It can originate from an acute inflammation or collection of pus in any organ of the body if the virulent micro-

organisms mentioned above, particularly the pus cocci, are carried off and lodged in the marrow. Mikulicz found the staphylococcus pyogenes aureus and albus occasionally in the discharges from aseptic wounds which healed by perfect primary union, and Fränkel demonstrated both kinds of cocci in the discharges accompanying inflammations of the pharyngeal cavity, and almost constantly in the normal pharynx.

Anatomical Changes in Acute Infectious Osteomyelitis.—The anatomical changes in acute infectious osteomyelitis are in the main the following: At the outset there is a diffuse hyperæmia of the medulla, and, later, yellowish or greyish-coloured foci of suppuration appear in it which not infrequently coalesce and form a single large collection of pus. In the severest cases there is observed a general suppuration of the medulla of the entire diaphysis—most commonly of the femur or tibia—with secondary collections of pus in the Haversian canals, between the periosteum and bone, in the periosteum, and in the adjoining soft parts. The periosteum probably becomes involved for the most part secondarily, and is the seat of an inflammatory infiltration and swelling (serous, sero-fibrinous periostitis). In this serous periostitis the exudate is usually very rich in albumen, and hence was called by Ollier periostitis albuminosa. Suppurative periostitis only occurs in the severer cases. As a rule, the pus in acute infectious osteomyelitis is rich in fat, in consequence of the acute degeneration of the medullary cells. Not infrequently the infectious matter—the cocci and the products of their metabolism—enter the circulation, causing death from septicæmia or pyæmia. The suppurative separation of the epiphyses at their junction with the diaphyses is a pathological change of considerable importance, as well as the secondary development of inflammations of the neighbouring joints either in the form of a transitory mild serous or sero-fibrinous inflammation, or of a severe suppurative arthritis. Haaga states that in four hundred and seventy cases, permanent, slight, or pronounced changes remained in the joints one hundred and eighty-nine times. Curvatures or angular deformities of bones sometimes develop after osteomyelitis (see page 614). Necrosis varying in amount even up to total necrosis of an entire diaphysis very often occurs in the diseased bone. Acute infectious osteomyelitis terminates either in a complete *restitutio ad integrum*, with or without suppuration, or in a varying amount of necrosis of the bone, or in death, particularly from pyæmia and septicæmia. Not infrequently encapsulated central bone abscesses are left behind which persist for years.

Osteomyelitis occurs either in a single bone, involving most commonly the diaphysis of the long hollow bones (femur, tibia), or as a

multiple affection in different bones. In the latter instance there is a simultaneous infection of several bones, or the primary disease in one bone gives rise to metastases in other bones. The short, flat bones most commonly affected are the clavicle, the ileum, and the scapula. After total necrosis of the clavicle the bone may be completely regenerated, its shape restored, and the function of the arm undisturbed.

Clinical Course of Acute Infectious Osteomyelitis.—The clinical course of acute infectious osteomyelitis varies greatly. The worst cases present the symptoms of a very severe constitutional disease, with high fever, delirium, rapid swelling of the affected bone, and death within a few days. In the mildest cases the local and constitutional manifestations are slight. The cases of moderate severity are probably the most common. The amount of constitutional infection does not always correspond to the extent of the local disease. The fever in the severe cases is, as a rule, very high, reaching 41° C. (104·1° F.). The disease generally begins with a chill two to three days after a traumatism, for example, or exposure to cold, and during the days immediately following the local disease can usually be readily made out in one bone, less often in several bones. The intense pain, the even swelling, the absence at first of any fluctuation or inflammation of the soft parts, and the pronounced disturbance of function are in general characteristic of the local disease of the bone. Many cases do not begin so acutely; on the contrary, they often commence very gradually. Occasionally the disease runs a course which presents the picture of an acute articular rheumatism with inflammation of the large joints. In these cases the osteomyelitis is always multiple, and the inflammation of the joints (secondary to disease of the neighbouring epiphyses) often goes on to suppuration.

The subsequent course of acute infectious osteomyelitis is in the majority of instances favourable. In the mildest cases complete *restitutio ad integrum* takes place in two to three to four weeks without any noticeable suppuration. In the severest cases the suppuration of the medulla runs a very rapid course, accompanied by secondary suppuration of the periosteum and phlegmonous sloughing of the soft parts, sometimes with the evolution of gas. Death in such cases generally occurs from what looks like septicæmia with severe typhoid symptoms, or from pyæmia with secondary abscesses in the internal organs. Probably the most common termination is recovery, with necrosis corresponding to the amount of bone which has been affected. The necrosis is usually a central one—i. e., it is limited to the bone substance adjoining the medulla. But if there is extensive suppuration in the medulla and periosteum the entire diaphysis of a long bone may die. Not infrequently circumscribed collections of pus in the medullary cavity be-

come encapsulated and form abscesses running a chronic course without necrosis, and leading to a characteristic diffuse thickening of the affected bone. The suppurative separation of the epiphyses is another complication occurring in young subjects when the suppuration invades these parts. The epiphyseal separation, as in fractures or traumatic separations, is recognised by the abnormal mobility. Usually there is only separation of one epiphyses, which in the femur, for example, is the lower; only in rare instances are both involved. The separation of both epiphyses of a single bone appears to have occurred most commonly in the tibia.

The secondary inflammations of the joints which accompany acute infectious osteomyelitis are either acute or subacute serous inflammations, or severe suppurative forms, which may even be attended by the evolution of gas.

Sometimes, after an acute osteomyelitis has run its course, even when no extensive necrosis has taken place, the bone may be left abnormally soft. It may lose its strength to such an extent that curvature, angular deformity, or axial rotation of the diaphysis of a bone, like the femur, may be produced by muscular action and by the superimposed weight of the body (Stahl, Oberst, and others). In such cases of curvature or deformity the bones involved are remarkably porous, and at the point where the disease is located a fistula will generally be found which leads to a focus of rarefied bone with a sequestrum.

As Krause has correctly stated, the osteomyelitic cocci appear to possess great powers of resistance, since renewed formation of pus has been observed in old osteomyelitic areas even after the lapse of years. This is the explanation for those cases of multiple osteomyelitis in which the foci of the process have apparently completely disappeared, but in which, nevertheless, suppuration and necrosis subsequently develop.

Diagnosis and Prognosis of Acute Osteomyelitis.—The diagnosis of acute infectious osteomyelitis can be made from what has been stated about the anatomical changes and the symptomatology.

The prognosis, in the majority of cases, is favourable *quoad vitam*. But it must be borne in mind that the disease may cause death at any stage, so long as an escape is not provided for the pus by chiselling open the medullary cavity. Many cases, especially those caused by the streptococcus, run a rapidly fatal course. After the suppuration has subsided, it is mainly the extent of the necrosis, the amount of inflammation which has occurred in the joints, the condition of the epiphyses, etc., which determine the character of the case.

The Treatment of Acute Infectious Osteomyelitis.—The treatment of

acute primary osteomyelitis has gained in efficacy with our knowledge of the etiology of the disease. In the treatment, a distinction must be made between the severe cases, which run a very acute course, and those which are mild and subacute. In the severest cases with high fever, a means of escape should be provided for the pus as soon as possible by making, under antiseptic precautions, a long incision down to the bone, at the point of greatest tenderness, or where the periosteum is swollen, and then cutting with the hammer and chisel a large enough opening into the medullary cavity in the shape of a gutter. If operative measures are adopted early enough, the otherwise unavoidable necrosis of the bone and the breaking through of pus into a neighbouring joint may sometimes be prevented, and the course of the disease will thus be rendered milder and shorter than it otherwise would be. To avoid recurrences and to obtain speedy recovery, it will often be found a better plan, instead of making a gutter-shaped opening into the medullary cavity of a long, hollow bone, to remove all of the bone except a wall of cortex (Riedel). This early scraping out of the infected medulla has recently been energetically supported by Tscherning (Copenhagen), Thelen, and others, and is in every respect a rational procedure, when it is remembered that we have to deal essentially with a cellulitis of the medulla; and in the case of any cellulitis it should be our aim to evacuate the pus at the earliest possible moment. It is not always easy to decide in what cases the aseptic opening of the diseased bone with the chisel should be attempted; moreover, many cases run such a rapidly fatal course that the correct diagnosis cannot be made at an early enough period. The evacuation of pus from bones, such as those of the pelvis, is difficult, and I have seen very severe cases involving just these bones where death occurred quickly. After opening the medullary cavity of a long hollow bone, the suppurative focus should be scraped out, and, if necessary, the entire medullary cavity. The periosteum and soft parts should likewise be carefully examined for the presence of pus, and, if found, it should be let out by incision and drainage. Finally, the medullary cavity should be disinfected as carefully as possible with a one-tenth-per-cent. solution of bichloride of mercury or a three-per-cent. solution of carbolic acid, and then filled with iodoform gauze, over which is placed an antiseptic protective dressing. Permanent antiseptic irrigation (see page 178) can be used with advantage for severe cases, instead of the antiseptic protective dressing. Immobilisation of the extremity in the best possible position by splints, etc., cannot be emphasised too strongly. Unfortunately, in spite of energetic and early operative local treatment, some of the severe cases will die in consequence of the systemic intoxi-

cation already present, which even an amputation or a total subperiosteal resection of the diseased bone will not always prevent. Complete resection of the bone—i. e., the removal of the diseased bone *in toto*—seems to me very inadvisable, as its efficacy has as yet not been sufficiently established. Amputation in the acute stage is rarely indicated, though it may be in the later stages, when suppuration becomes so excessive as to threaten to carry off the patient from exhaustion.

In the moderately severe and the mild cases the local treatment consists in the energetic application of ice, in placing the extremity in an elevated position, and in immobilising it as much as possible with a splint. Others prefer moist heat to ice for alleviating the pain. I consider that the application of iodine, which was formerly so much used, has but little effect. If there is marked swelling of the periosteum and the pain due to this is severe, even though no pus can be obtained by a test puncture, I nevertheless advocate early incisions to lessen the tension, and thus ease the patient's pain. Furthermore, it is possible by this means to prevent, or at any rate to lessen, a subsequent necrosis of the bone. Not infrequently cases which were at the outset mild, become so severe that it may be necessary to chisel a groove into the medullary cavity and drain or pack the latter with iodoform gauze.

As regards the treatment of complications the following should be noted: Inflammations of joints are treated according to the general principles applicable to these affections (see Diseases of Joints). If suppuration occurs, the joint should be opened and drained as soon as possible. Separations of the epiphyses are treated in the same way as a fracture. Curvatures of bone following osteomyelitis can sometimes be overcome, after scraping out the osteomyelitic focus and removing the sequestrum which may be present, by extension with a heavy weight (five to ten kilogrammes). The treatment of the necrosis which is so common a result of osteomyelitis is described in § 106.

Amputation accompanied by Scraping out the Bone Stump.—Perkowsky practised amputation in eight severe cases of osteomyelitis, and then scraped out the medullary cavity of the diseased bone stump, removing in three cases the medulla of the entire stump with the sharp spoon, so that only a thin shell of bone was left. Necrosis did not take place in a single case, and a rapid recovery followed in all eight cases under iodoform dressings. Perkowsky thus avoided disarticulation or amputation of the limb at a higher point.

The treatment of acute periostitis occurring by itself is conducted according to the general rules which apply to inflammation. If the acute periostitis is suppurative, incision is employed; if not suppurative, antiphlogesis.

The Acute Traumatic Inflammations of the Periosteum and Medulla.—Acute traumatic inflammations of the periosteum and medulla are observed after injuries of various kinds, such as contusions, wounds of the periosteum, subcutaneous and compound fractures, wounds of bone, etc. Acute non-suppurative periostitis and osteomyelitis traumatica take place after every contusion and subcutaneous fracture. The suppurative form is always caused by infection with bacteria which enter through some wound or circulate in the blood. This includes, moreover, the acute osteomyelitis of the amputation stump which, especially in the days before antisepsis, terminated in death from pyæmia. At present we have learned to avoid this form of osteomyelitis with certainty in our amputations by employing antisepsis and asepsis. The anatomical changes and the cause of the acute (traumatic) periostitis and osteomyelitis are essentially the same as in the above-described spontaneous acute infectious osteomyelitis and periostitis.

Metastatic Inflammations of Bone.—The metastatic inflammations of bone in pyæmia, typhoid and scarlet fevers, measles, small-pox, etc., are either analogous to the spontaneous acute infectious osteomyelitis and periostitis, or they run a chronic course with the formation of circumscribed cold abscesses. The inflammations of bone occurring in the course of typhoid fever are mainly observed in the ribs, where they become localised as a chondritis or perichondritis, having a very chronic course; typhoid bacilli have repeatedly been demonstrated in the inflammatory foci (Bergmann, Potter, etc.). In the cases of metastatic bone inflammation from plugging of the vessels by emboli, a corresponding necrosis of bone occurs which is called an "embolic necrosis." Such embolic necroses from obstruction to the afferent flow of blood are occasionally observed in endocarditic processes, when blood-clots with or without micro-organisms break loose from the growths on the endocardium and are swept away and lodge in the bones. Epiphyseal separations and secondary joint diseases, which were described above, may also accompany metastatic periostitis and osteomyelitis.

Growth Fever.—In young subjects there is occasionally observed a marked temporary tenderness to pressure in the epiphyses of the long bones, especially the femur, humerus, and tibia, accompanied by inflammatory irritation of the neighbouring joints, with the manifestations of fever and a corresponding disturbance of the general health. Bouilly and Juillier have designated this condition as growth fever. It is a question whether in such cases there may not sometimes be present a true acute infectious osteomyelitis of the mildest kind, which terminates in *restitutio ad integrum*.

Embolic Foreign-Body Inflammations of Bone.—Great interest attaches to the embolic foreign-body inflammations of bone which are observed

in mother-of-pearl turners and workers in woollen and jute mills. People employed in these occupations breathe in the particles of mother-of-pearl dust, wool, or jute, which then pass from the lungs into the circulation and lodge in the small arteries of the medullary portion of the bones, particularly the terminal arteries at the extremities of the diaphysis, and here excite embolic inflammation of the medulla with secondary involvement of the periosteum. As is the case with acute infectious osteomyelitis and periostitis, youthful individuals are the ones who are principally affected by these inflammations of the medulla in the diaphyseal ends of the bones and in the epiphyses. Gussenbaur, Englisch and Levy have given accurate descriptions of the inflammations of bone to which mother-of-pearl turners are subject. The symptoms consist in very painful swellings, which usually appear suddenly at the ends of the diaphyses with marked swelling of the periosteum. The course of the affection is generally subacute, and suppuration has as yet never been observed. *Restitutio ad integrum* ordinarily follows, the worst that happens being a thickening of the periosteum, which persists for a greater or less length of time. But if the turners resume their occupation, recurrences of the inflammation are frequently observed, which run a chronic course, with thickening of the spongy bones of the carpus or tarsus, or of the diaphyseal ends of the long bones.

Klein has described the bone disease of jute spinners. In this, too, there is an inflammation of the medulla and periosteum in the region of the epiphyseal cartilages, accompanied by severe pain. A considerable growth of epiphyseal cartilage usually takes place, giving rise to secondary curvature of the bones, particularly the tibia. In this affection also suppuration or necrosis never occurs.

§ 105. **The Chronic Inflammations of Bone** (*Chronic Periostitis, Ostitis, and Osteomyelitis*).—The most important chronic diseases of bone are the mycotic, of which the tubercular, syphilitic and actinomycotic inflammations of bone are prominent examples. Furthermore, acute infectious diseases, such as measles, scarlatina, typhoid fever, etc., may be followed not only by acute inflammations of bone, as mentioned above, but also by inflammations which are at first latent, and then subsequently manifest themselves as affections running a chronic course. The chronic inflammation of the ribs which follows typhoid fever is an example of this class of cases (see page 617). The other chronic inflammations of bone are mostly secondary to preceding acute inflammations, and include, as a terminal stage of the latter, necrosis. Chronic inflammations of bone are also sometimes the result of the extension to the latter of chronic inflammation in the surrounding parts. The

changes which occur in bone in consequence of chronic inflammation consist either in a destruction of the bone substance (caries, necrosis) or in a reactive new formation of bone.

Chronic Periostitis.—Amongst the various forms of chronic periostitis, mention should first be made of the periostitis chronica fibrosa. In this variety tough, fibrous thickenings of the periosteum develop, sometimes with absorption of the superficial portions of the bone (caries superficialis), and sometimes with new formation of bone. In the latter instance the process is an ossifying periostitis.

Periostitis Albuminosa or Mucinosa (Non-purulenta).—Poncet and Ollier were the first to describe a peculiar form of periostitis under the name of periostitis albuminosa (ganglion periostale), concerning the nature of which different authorities hold very divergent views. The affection attacks almost exclusively the ends of the diaphysis of the long, hollow bones in young subjects from fifteen to twenty years of age, and involves not only the periosteum but frequently the bone also (ostitis albuminosa). Schlange has proposed calling it periostitis and ostitis non-purulenta, and Riedinger periostitis mucinosa. As a rule, the disease begins with severe pain, swelling at the lower end of the diaphysis in the neighbourhood of the epiphyseal line, and fever, as is the case in acute primary osteomyelitis. After a few days the fever and pain disappear, and the swelling of the periosteum and bone becomes more and more prominent. There will be found at the diseased point, instead of pus, either a bloody serous or a hydrocele- or synovial-like fluid which has the consistency of tenacious mucus. The fluid lies either beneath the periosteum, or within it in the form of a cyst, or on its outer surface, and in the latter instance there is also a diffuse œdematous swelling of the surrounding soft parts. The periostitis and ostitis albuminosa, or non-purulenta, or mucinosa, is not tubercular in its nature, but is possibly a non-suppurative osteomyelitis and periostitis caused by weakened, attenuated pus cocci; it resembles an inflammation which has not passed beyond the serous stage. Pus cocci, including the staphylococcus pyogenes albus and also the aureus, have been repeatedly demonstrated in periostitis albuminosa. Vollert states that a mucoid metamorphosis of the leucocytes takes place in this affection.

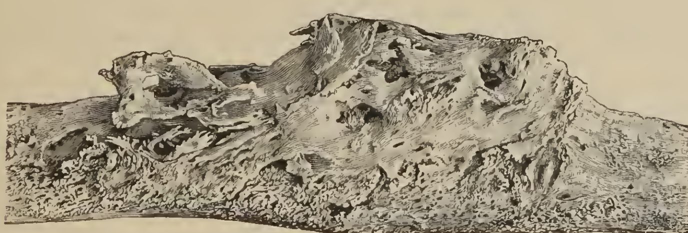


Fig. 348.—Osteophyte (Pathological museum at Leipsic).

Its course is very chronic, and necrosis of the bone is often present. The disease is very rebellious to therapeutic measures, and recurrences frequently

take place, or fistulæ may persist for months or years. The best treatment consists in incision and energetic scraping out of the underlying diseased bone, with or without chiselling an opening into the medullary cavity. Cystic formations should be carefully extirpated.

Fig. 349.—Hyperostosis (elephantiasis) of the femur (Pathological museum at Leipsic).

In the periostitis chronica ossificans the new formation of bone is either limited to a circumscribed portion of the bone, giving rise to what is called an osteophyte (Fig. 348), or diffuse hypertrophies—hyperostoses, as they are called—are developed, in consequence of which thickenings of the bone resembling elephantiasis result (Fig. 349).

In addition to chronic fibrous and chronic ossifying periostitis, we recognise a chronic suppurative periostitis, which sometimes is the terminal stage of an acute periostitis and sometimes develops gradually as a disease by itself, and chiefly comes into consideration as a concomitant phenomenon of necrosis or caries of bone. In chronic suppurative periostitis we have to deal, for the most part, with specific processes, such as tuberculosis, syphilis, or actinomycosis, and also with necrosis of bone from various causes. Tubercular periostitis is either primary or secondary to tuberculosis of bone or its medulla, or of the surrounding soft parts.

Treatment of Chronic Periostitis.—Chronic non-suppurative periostitis should be treated briefly as follows: First of all its cause should be determined and proper steps taken to remedy it. To relieve the tension, pain, and local inflammatory symptoms, incisions and hydropathic applications can be used with advantage. It is also an excellent plan to paint the parts with tinct. iodi fortior alcoh. (five parts iod. pur. to 30·0 of alcohol). Compression by the elastic bandage is of use for the fibrous thickening and osteophytes; but troublesome osteophytes, occurring, for example, in connection with an ulcer of the leg or some other disease of the soft parts, should be removed with the hammer and chisel.

The treatment of chronic suppurative periostitis is likewise mainly determined by the cause, and we shall discuss this disease more fully under Tuberculosis, Caries, and Necrosis, etc. (see also Syphilis, § 84, and page 626).

Tuberculosis of Bone.—One of the most important and by far the most common of chronic bone diseases is tuberculosis (ostitis tuberculosa, caries tuberculosa or fungosa), which occurs chiefly as tubercular periostitis and osteomyelitis, and leads to extensive destruction of bone —to caries, as it is called (Fig. 350)—and to necrosis. Volkmann in particular has won lasting honours by his studies upon the subject of tuberculosis of bones and joints, and Robert Koch has greatly advanced our knowledge upon the etiology of tubercular inflammation by demonstrating and obtaining in pure cultures the tubercle bacillus (§ 83). We now know that all those forms of inflammation which affect bone, and have been designated as caries, spina ventosa, scrofulous or fungous inflammation of bones and joints, tumor albus, etc., are in the main true tubercular inflammations.

Tubercular inflammation of bone occurs most commonly in young individuals—i. e., in growing bone—for the reason mentioned before, namely, that the formed foreign elements circulating in the blood, particularly the tubercle bacilli, are more readily deposited in the branches of the vessels in growing bone, although tuberculosis also occurs during the later years of life, and may be met with even in extreme old age. The poison of tuberculosis, the tubercle bacilli, are generally carried to the bones by means of the blood-vessels, as can be easily proved by experiments on animals. Traumatic injuries of bone, as we remarked before, favour the development of tuberculosis. Tuberculosis of bone may, moreover, be due to the direct extension to the latter of a tubercular process in the surrounding tissues, such as the skin, subcutaneous tissue, tendon sheaths, synovial membrane, etc. Tubercular inflammations of the vertebræ and of the bones of the hands and feet are the most common.

Anatomical Changes in Tuberculosis of Bone.—Tuberculosis of bone almost always begins with the formation of circumscribed foci in the periosteum, in the epiphyses of the long bones, or in the medulla, particularly in the spongiosa of the short bones (Fig. 351); less commonly the disease is more diffuse. The tubercular focus often remains for a long time the size of a pea or a hazel-nut, and then enlarges by direct extension from its edges or by the development of new foci in the region surrounding the primary one. The individual foci then coalesce, and thus large tubercular foci or diffuse processes originate. Not infrequently several distinct foci are observed in one and the same

bone, or tubercular inflammations occur in different bones at the same time or one after the other. The tubercular focus is made up of the characteristic tubercles which originate from the lodgement and growth of the tubercle bacilli, and have been minutely described on page 408. Wherever a tubercular focus develops in bone (Fig. 351), caries results—i. e., the bone disappears in the form of lacunar absorption (see Fig. 343)—while the focus itself sooner or later becomes the seat of a cheesy degeneration beginning in its centre. If the bone has not been destroyed at the time that caseation of the tubercular focus occurs, mortification of the bone then takes place *in toto*—i. e., a so-called tubercular sequestrum forms which becomes separated from the surrounding parts by a demarcating suppuration. In the later stages the tubercular sequestrum lies completely free in a cavity of greater or less size, containing cheesy, flocculent pus, with or

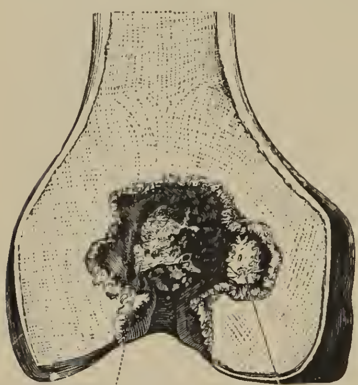


Fig. 350.—Tuberculosis of the lower epiphysis of the femur, with two sequestra (*a*). The process has broken through into the knee-joint (Weber).

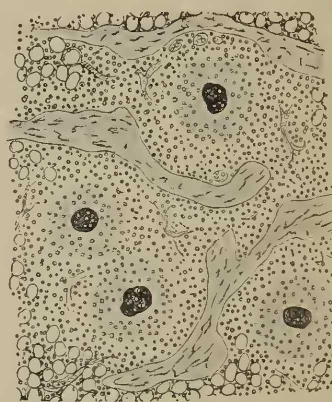


Fig. 351.—Fungous granulations with tubercles (*Tu*) in the cancellous portion of the talus: *K*, intact trabecula of bone.

without fistulæ opening externally (Fig. 350). In general the characteristic tubercular sequestrum is a larger or smaller caseated concretion of bone through which has grown tubercular or caseous granulation tissue. Very often the entire tubercular focus becomes softened and liquefied *in toto* without the formation of a sequestrum. The central abscesses of bone, which exist for years, are partly due to tubercular processes, partly to a preceding primary acute infectious osteomyelitis, and partly to metastasis in the course of acute infectious diseases.

A reactive deposit of bone often takes place around the tubercular focus in the bone or its medulla, causing it to become more or less completely enclosed by thickened, sclerotic bone tissue. In the pronounced cases of sclerosis of bone the bony structure becomes as dense

as ivory (so-called eburnatio ossis), and the medullary cavity may be completely obliterated. But in other instances all traces of reactive hyperplasia of bone are absent, even though the tubercular inflammation has existed for years.

In the tuberculosis of bone there are also formed sacculated collections of pus—cold abscesses—which are enclosed in a characteristic so-called pyogenic membrane consisting of connective tissue and granulation tissue containing tubercles. The abscesses either rupture externally in the region where they originated, or the force of gravity causes them to sink lower. In the case of tubercular inflammation of the cervical and thoracic vertebræ, for example, they descend along the anterior surface of the vertebræ, following the course of the psoas muscle, and appear beneath Poupart's ligament (so-called congestion abscesses). These congestion abscesses extend in a perfectly typical manner, which is governed by the anatomical conditions—i. e., they follow the natural spaces between the tissues corresponding to the arrangement of the fasciæ and aponeuroses.

The caries which accompanies tuberculosis is often—in the case of the vertebræ, for example—very considerable. In consequence of this there develops in the back the so-called kyphosis or Pott's hump, named after the English surgeon Percival Pott, who first described this disease. Marked destructive changes also take place in the small bones and articular ends of the long ones, leading to deformities of various kinds, with subluxations and complete dislocations of the deformed articular extremities of the bones. In the fingers and toes tuberculosis usually occurs as a tubercular osteomyelitis, with a spindle-shaped enlargement of the bone (*spina ventosa*). In this condition the cortex of the bone becomes constantly thinner in consequence of the tubercular osteomyelitis, while at the same time, as a result of the reactive periostitis, osteophytes are formed. Spina ventosa often heals without suppuration or necrosis having taken place, and with a spontaneous and complete *restitutio ad integrum.* The same form of tuberculosis also occurs in the long bones, such as the tibia and femur.

The most common site of bone tuberculosis in the long, hollow bones, whether located in the periosteum or in the interior of the bone, is in the region of the epiphyses. This is the reason why secondary tuberculosis of the joints is so common (see § 114, Tuberculosis of Joints). Tuberculosis of the diaphysis of a bone is comparatively rare —a fact of great diagnostic importance, especially in the case of adults. Consequently, if the shaft of a bone is diseased, particularly in an adult, we think of syphilitic or some other bone disease before tuberculosis.

As regards other bones, tuberculosis is especially common in the

bones of the skull, in the orbital portion of the superior maxilla, in the ribs, and particularly in the spinal column and the bones of the carpus and tarsus.

Under the microscope, tuberculosis of bone presents a picture which corresponds to the tubercular inflammation described in § 83. Koch's tubercle bacilli will be found most abundantly where the tubercular process is beginning, the best method of staining being that of Ehrlich's, with fuchsin or gentian violet. Nevertheless, their demonstration in tuberculosis of bone is sometimes very difficult, or even impossible—a fact which has been commented upon before. In tuberculosis of bones and joints Müller frequently found peculiar bodies resembling fat drops, which not uncommonly were surrounded by minute granules, and, like these, were characterised by taking on a deep red or violet stain. These bodies probably bear some relationship to the bacilli.

The Clinical Course of Bone Tuberculosis.—The clinical course of tuberculosis of bone is usually very chronic. There are often symptoms of tuberculosis in other organs—the lungs, for instance—at the same time. Heredity is important—i. e., tuberculosis of the parents or grandparents or other near relatives. Quite often it happens that for a long time symptoms peculiar to tuberculosis of bone are absent; severe pain especially may long be missed, unless a neighbouring joint, the periosteum, or overlying parts are attacked by the tubercular inflammation. In the majority of instances the symptoms pointing to tubercular inflammation will not make their appearance till after the disease has existed for months, the development of an appreciable tumour, particularly if the tuberculosis is periosteal, being the first intimation of the process. But even if the tuberculosis is located in the bone or medullary cavity, an appreciable tumour will sometimes be formed after several months in consequence of a thickening of the bone, while in other instances, though the tuberculosis may have existed for years, all swelling will be absent. Under these conditions the diagnosis can often only be made when the periosteum begins to become involved in the inflammation, and there is tenderness on pressure over the area in question, or when œdema of the skin is present. As the tuberculosis advances the symptoms become more pronounced, especially the swelling at the diseased spot, the pain, particularly if the tuberculosis is located in the medulla, the disturbance of function, the development of fistulæ, burrowing of pus, etc. The disturbance of function is most pronounced in tuberculosis of the epiphysis in the neighbourhood of a large joint like the hip or knee. The tumefaction accompanying tubercular infiltration of the periosteum or medulla is either due to osteophyte formation, or the bone is puffed out, as it were, by tubercular osteomyelitis,

in the manner which we described as occurring in spina ventosa of the phalanges of the fingers. In this spina ventosa of the fingers the bone may feel firm, or elastic and thin. After a certain length of time the tubercular pus works its way outwards and breaks spontaneously through the skin, and the thin liquid, usually mixed with cheesy flocculi, is discharged. Fistulous ulcers with a cheesy base and undermined edges then develop from the fistulæ. If a probe is passed through the fistula it either immediately comes in contact with the bone, or penetrates into the medullary cavity. The other secondary manifestations of tuberculosis, the cold or congestion abscesses, etc., have been sufficiently described, and we need only call attention to the fact that the latter do not heal up until the original focus which gave rise to them has disappeared. Their course is usually very tedious, especially in the case of tubercular inflammation of the spine. The tubercular inflammations of joints are discussed in § 114. A tubercular deposit in the periosteum or medulla of an epiphysis, lying in immediate proximity to a joint, often works its way to the surface *extra-articularly*, and leaves the joint intact.

The general health in tuberculosis of bone is very often but little or not at all affected. There is frequently a slight fever, varying with the extent of the process. It is a common occurrence to find that the general health is only slightly disturbed even when extensive multiple tuberculosis is present. In general the fever is most pronounced *before* the tubercular inflammation has extended beyond the bone, but it is usually slight, and, as a rule, disappears more or less completely when the inflammation has worked its way to the surface of the body.

Diagnosis of Bone Tuberculosis.—The diagnosis of tuberculosis of bone is easy in the case of primary tubercular periostitis, particularly if the bone is superficial, and the characteristic swelling, tenderness on pressure, etc., are present. The diagnosis of bone tuberculosis may occasionally be doubtful for some time, but still its beginning and subsequent course in different parts of the body, as we shall see in the Special Surgery, is generally so typical that the diagnosis is not very difficult (see also § 83, Tuberculosis).

Prognosis of Bone Tuberculosis.—As regards the termination and the prognosis of tuberculosis of bone, I must refer the reader to what has been stated in § 83. Suffice it to say that the location of tuberculosis of bone plays a very important part as regards prognosis—i. e., in so far as it determines whether the existing focus can be completely removed by operative measures at the earliest possible stage, or whether other local treatment, such as iodoform injections, can be employed. If the latter is impracticable, as may often be the case in tuberculosis

of the vertebræ, spontaneous recovery can probably only take place when the focus is not too large. In the majority of instances the tubercular disease steadily progresses or very often leads to tubercular systemic infection. Recurrences in tuberculosis are pretty common, and permanent cures do not occur so frequently as many enthusiasts believe (see § 83).

The Treatment of Tuberculosis of Bone.—In the first stages of a developing tuberculosis of bone the treatment is purely symptomatic (rest, immobilising dressings, ice, good food, fresh air, etc.). As soon as possible I then begin in suitable cases with parenchymatous injections of sterilised ten per cent. iodoform oil, or the iodoform glycerine of Bruns, which I can most heartily recommend (two to eight grammes every two to four weeks). At present I always use ten-per-cent. iodoform oil. The iodoform and oil are sterilised separately by heating them in a sterilising apparatus to 100° C. (212° F.); the sterilised materials are then cooled and made into a ten-per-cent. iodoform mixture in a sterilised vessel. Instead of ol. olivæ, Böhm recommends ol. amygd. dulc., in which is dissolved fifty per cent. of iodoform. If the iodoform oil is prepared in the manner described above, we avoid the injurious effects or poisonous manifestations of the iodoform, which are mainly caused by the liberation of iodine. The latter is particularly apt to be set free if the iodoform and oil are sterilised together at high temperatures when in the form of an emulsion. Lannelongue praises the results obtained by the injection of strong solutions of chloride of zinc into the periphery of the tubercular focus; a contracting, cicatrix-like tissue is thus produced, which forms an obstruction to the spread of the tubercular process and causes the death of the tubercular focus. I have little to say in favour of parenchymatous injections of three-per-cent. solutions of carbolic acid or arsenic. Balsam of Peru and cinnamic acid are spoken of on page 420. Nannotti recommends oil of cloves (ten per cent., with olive oil); Reboul, naphthol camphré obtained by mixing and heating one hundred parts of finely powdered β naphthol with two hundred parts of finely powdered Japan camphor. The oily liquid of naphthol camphré is insoluble in water, but miscible with fats, ether, alcohol, and chloroform, and must be kept in a dark bottle. The remedy can be employed in various ways—as a wash, an injection, etc. Bouchard states that its toxic dose for adults is about two hundred and fifty grammes.

If treatment by drugs proves unsuccessful, and a marked focus of disease or of pus is present, operative treatment should be undertaken—i. e., the tubercular deposit should be removed as soon as possible, with strict regard to antisepsis. Operations on the extremities are performed

under Esmarch's artificial ischæmia, which renders it possible to easily distinguish the healthy from the diseased parts. Free incisions should always be made, in order that the focus may be inspected throughout its entire extent. Mosetig-Moorhof finds an electric lamp useful for this purpose. If the tuberculosis is in the medulla, the bone should be opened sufficiently with the chisel and hammer, and the tubercular focus should be energetically removed with the sharp spoon. The scraping-out process must be continued until healthy, firm bone is reached. Even when the entire medullary cavity of a long bone has to be thus scraped out, necrosis will not occur if only the wound in the bone heals aseptically. To prevent recurrences and to render speedy recovery possible, Riedel recommends extensive removal of the bone, leaving only a thin wall of cortex intact. Free sequestra should be extracted; infected soft parts in the neighbourhood of the diseased bone, abscess membranes, etc., should likewise be removed with the greatest care by scissors and forceps. After having scraped out the tubercular deposit in the bone, the resulting cavity should be filled with ten per cent. iodoform oil and packed with iodoform gauze. Billroth's method is most excellent and efficacious. The tubercular cavity, in case it has not opened externally before the operation, is immediately filled with ten per cent. iodoform oil or iodoform glycerine, and hermetically closed after all tubercular tissue has been removed with the sharp spoon. The iodoform acts more effectively in the absence of air.

If any recurrences take place, they are soon recognised by the persistence of fistulæ with fungous tissue. The secondary operation should not be delayed too long. Operations must often be performed two, three, or more times, with short intervals, before a complete cure is obtained. The cold abscess, which used to be a *noli me tangere* to the old surgeons on account of the pyæmia which so frequently followed the operation, must always be opened at the earliest possible moment, scraped out and drained. The treatment of tubercular inflammations of joints will be discussed under the subject of Diseases of Joints (§ 114). The indications for amputation and resection are described on pages 113 and 129. All operations in cases of tuberculosis should be performed with the greatest care and most rigid asepsis. We mentioned, in first speaking of tuberculosis, that general miliary tuberculosis may occasionally follow operations on tubercular foci, as well as vigorous movements of joints affected with tubercular disease.

Iodoform and iodoform gauze are the best materials for dressings in cases of tuberculosis, and large wounds may be packed with them. Instead of packing with iodoform gauze, Schede's plan of obtaining healing under an aseptic blood-clot without drainage is

also very serviceable after scraping out the tubercular deposit (see page 102).

The treatment of tuberculosis of bone with Koch's tuberculin is discussed on page 421. I have obtained no permanent cures by this means, and sometimes matters have been made decidedly worse. Kraske, among others, has had the same experience.

In tuberculosis it is very important that the constitution of the patient should be strengthened by energetic general treatment, in the manner described on pages 421 and 424.

The Syphilitic Diseases of Bone.—Syphilis of bone occurs in the later stages of syphilis (§ 84), either in the form of death of bone, as caries and necrosis, or as an ossifying inflammation of bone. The inflammation of bone characteristic of syphilis is the gummatous periostitis and osteomyelitis—i. e., the formation of gummata or syphilomata in the periosteum or medulla. The periosteal gummata take the form of flat, elastic swellings, which on section reveal a gelatinous consistency.

In the later stages a fatty, cheesy, or a suppurative degeneration takes place, with or without shrinkage to firm fibrous thickenings. The periosteal gumma is very apt to occur on the skull, and also not infrequently in the periosteum inside the cranial cavity, less often on the clavicle, and rarely on the diaphyses of the long bones. The epiphyses of the latter and the short bones are, almost without exception, exempt from gummata.

The osteomyelitic gummatous nodes are soft or more fibrous gelatinous formations, varying from about the size of a pea to that of a nut, and usually cheesy in the centre. They are sometimes multiple, being found, for example, on the skull, on the phalanges, and, according to Chiari, also on the long bones, the femur and tibia being the most frequently affected.

Both periosteal and osteomyelitic gummata destroy the bone to a greater or less extent, and lead to a varying amount of superficial or central caries with necrosis. In consequence of this death of bone fractures readily occur, and not infrequently are followed by pseudarthrosis. The syphilitic caries with necrosis is particularly apt to make its appearance on the skull, and sometimes is very extensive (see Special Surgery). A reactive new formation of bone also occurs as a result of the gummatous periostitis and osteomyelitis; it leads to the development of osteophytes of varying dimensions, and also to hypertrophy and sclerosis of the bone.

The gummata either disappear under appropriate antisyphilitic treatment by becoming gradually absorbed and replaced by dense cica-

tricial tissue or newly formed bone tissue, or else a spreading destruction and necrosis of bone develops, the gummata open externally, etc.

Apart from the reactive development of new bone with the formation of osteophytes and diffuse hyperostoses accompanying gummata, there is also an independent ossifying syphilitic ostitis, a periostitis and osteomyelitis, which occur alone.

In congenital syphilis there is observed a characteristic disease of the bones in the neighbourhood of the epiphyses, consisting in some cases in an abnormity in the deposit of lime, and in the formation of medullary spaces such as occurs in rhachitis. This syphilitic rhachitis is not very common. But in other cases of congenital syphilis a very characteristic localised disease is present in the epiphyses, particularly in the part near the articular and epiphyseal cartilages. This syphilitic osteochondritis of infants, first described by Wegner, is in fact a common though not a constant manifestation of hereditary syphilis. The disease consists in the formation of greyish-red or yellowish-grey foci in the medulla of the epiphyses in the neighbourhood of the articular and epiphyseal cartilages. The bone becomes replaced by a soft granulation tissue, and the cartilage itself is in a state of inflammatory growth. Separation of the epiphysis sometimes occurs in syphilitic osteochondritis, as it does after acute infectious osteomyelitis. Kassowitz found this condition nine times in thirty-three cases. Epiphyseal separations have also not infrequently been observed in still-born syphilitic children (Haab, Veraguth, etc.), but under these circumstances the separations may possibly have been caused by putrefactive changes as well as by the syphilitic osteochondritis.

The course of the syphilitic inflammations of bone, which occur especially in the later so-called tertiary period of the disease and in the cases which have been improperly treated, is for the most part very chronic and marked by frequent relapses. They have been wrongly ascribed to the effects of mercury. Ostitis due to mercury is only observed as a result of salivation ulcers on the jaws. Traumatism appears to play an important part in the syphilitic inflammations of bone. The severe pains (dolores osteocopi), which occur principally at night, are often characteristic.

The treatment of the syphilitic inflammations of bone consists in the adoption of a general antisyphilitic regimen (see § 84). The local treatment of the syphilitic metastases is conducted according to general principles, and is similar to that briefly described for tuberculosis of bone.

The So-called Bone Abscess.—We have made repeated mention of the so-called chronic bone abscess which occurs, for example, after

acute infectious osteomyelitis and tuberculosis of bone. It is always infectious in its nature and arises in various diseases, and is not, as was once believed, an independent disease, but always a symptom or a result of a pre-existing specific disease. Hence it follows that the causes of abscess of bone vary very greatly. The acute suppurative inflammations of the periosteum and medulla, the tubercular and syphilitic inflammations of bone, etc., are especially conducive to the development of chronic bone abscesses. The so-called acute bone abscesses are essentially metastatic in their nature or originate as a primary acute infectious osteomyelitis.

The symptomatology and treatment of abscess of bone can be inferred from what has been said concerning acute and chronic suppuration of bone.

Other Bone Diseases: Actinomycosis; Glanders.—Amongst other chronic diseases of bone, I should mention actinomycosis and the circumscribed cheesy or suppurative inflammations which occur in the periosteum and medulla in the course of glanders. Both diseases have been described in § 78 and § 86.

§ 106. **Necrosis of Bone.**—We have repeatedly spoken of the death of bone or of a certain portion of bone—the so-called necrosis of bone—when discussing the subject of Injuries and Inflammations of Bone.

The causes of necrosis of bone are sometimes inflammatory and sometimes traumatic in their nature. In typical necrosis of bone there is almost always an interruption of the afferent flow of blood, less often a direct death of the bone substance. Amongst the special causes of necrosis the diseases of the periosteum and medulla are the most important. It is principally the suppurative form of periostitis which very frequently leads to necrosis; but any suppurative periostitis, as such, will not cause necrosis of bone until it has existed a long time and has extended to the contents of the Haversian canals. The suppurative periostitis is frequently the result of a necrosis due to other causes.

Necrosis is also produced by the various forms of ostitis and osteomyelitis when the bone tissue becomes unable to obtain nourishment, owing to the destruction of the medulla and the contents of the Haversian canals. In this class of cases comes, for example, the necrosis from suppurative osteomyelitis and tuberculosis of bone, mentioned in a previous chapter.

Suppurative inflammations of the surrounding parts and ulcerative processes which extend to and destroy the periosteum likewise lead to necrosis. In this manner is caused, for example, the necrosis of the nasal bones, which occurs in the course of syphilis from the extension

of ulceration in the nasal mucous membrane to the deeper parts (ozæna syphilitica).

The necrosis occurring in the course of typhoid fever and the acute exanthemata is due in some instances to metastatic periostitis and osteomyelitis, while in others it is probably a kind of inanition necrosis which is the result of the general disturbance of nutrition. As a matter of fact the state of the nutrition of such individuals is generally extremely bad, and they suffer for the same reason from gangrene of the ears and nose.

In rare instances necrotic foci in bone originate from emboli. Volkmann saw a multiple necrosis of the astragalus and tibia which followed the formation of coagula on the mitral valve in endocarditis. In these cases we generally have to do with multiple capillary emboli, and in the case of infectious processes these emboli may consist of micro-organisms which have entered the circulation. Embolism of a single nutrient artery of the bone would probably never be followed by appreciable consequences, for the reason that a collateral circulation readily develops, and the blood is carried to the bone by very many and for the most part very small vessels.

The phosphorus necrosis, first described by Lorinser, of Vienna, in 1845, is extremely interesting. It is observed in people employed in the manufacture of phosphorus matches, and is due to the injurious effects of the vapour of phosphorus. Phosphorus necrosis only affects the bones of the face, and selects the jaw almost always—the inferior maxilla more frequently than the superior. The disease regularly begins with inflammatory disturbances in the periosteum (phosphorus periostitis, Wegner), especially where there are diseased (carious) teeth. At first a chronic ossifying periostitis usually develops, then, as a result of infection by bacteria in the oral cavity, suppuration and gangrene follow between the periosteum and new bone, or between the new and old bone. Sometimes, though rarely, the disease begins immediately with suppuration and necrosis without a preceding ossifying periostitis. The entire lower jaw may become necrotic, especially if the process is not arrested by early removal of the focus of disease. Häckel states that the average duration of the disease from the time the periostitis begins till the suppuration and necrosis of the under jaw, for example, ceases, is, when the disease is left to itself—for the inferior maxilla two years nine and a half months, and for the superior maxilla one year and two months. Since the manufacture of phosphorus matches has become less extensive, and strict hygienic regulations have been enforced in the factories, phosphorus necrosis has become rare; but it still occurs in regions such as the Thuringian Forest, where the making of phosphorus matches is carried on as a family industry.

Necrosis develops after a traumatism, particularly if portions of the bone are completely torn off or separated from their attachments—a fact which we learned when discussing fractures (see § 101). We stated at that time that in fractures which heal aseptically and in those which are subcutaneous, pieces of bone which have been completely detached may again heal in place and not undergo necrosis. After subcutaneous dislocation of the astragalus, Winiwarter observed total necrosis of the bone occur in two instances in spite of its having been carefully replaced. Furthermore, when a bone has been severely splintered and crushed, circumscribed necrosis is particularly apt to develop if the arterial vessels in the medullary space or narrow Haversian canals are compressed—by an extravasation of blood, for example. Traumatic separation of the periosteum laying bare the bone does not of itself lead to necrosis, but the latter will develop if the bone becomes dry from long contact with the air, or if suppuration takes place.

Fig. 352.—Necrosis of bone (femur): *a*, sequestrum.

Anatomical Changes in Necrosis; Separation of the Sequestrum (Demarcation).—When a portion of a bone has perished it is gradually separated or set free from the surrounding living bone by a demarcating inflammation. The separation of the dead bone—the demarcation, as it is called—is designated anatomically as a granulating, rarefying ostitis, the bone disappearing by lacunar absorption (see Fig. 343) along the line of demarcation. The piece of bone, after it has become completely separated, is called a sequestrum (Fig. 352, *a*, and Fig. 353, *s*). The outer, periosteal, cortical surface of the sequestrum ordinarily remains smooth, while the other portions of the sequestrum, where it is gradually set free from the living bone by the demarcation, appear rough and uneven,

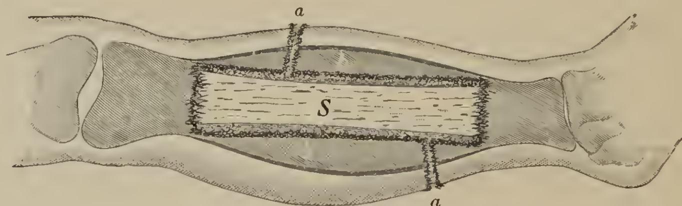


Fig. 353.—Complete necrosis of the diaphysis of the tibia: *S*, sequestrum; *a a*, fistulæ (cloacæ); *b*, newly formed bone or involucrum (schematic).

just like the ivory pegs which have been driven into a bone for pseudarthrosis (see Fig. 347). The size of every sequestrum is rendered

less by this corrosion or abrasion, and, in fact, small sequestra, like small splinters of bone in fractures, may be completely absorbed if there is no suppuration and the granulating germinal tissue surrounds them closely. As is the case in the corrosion of the ivory pegs, so also in the separation of the sequestra and the absorption of small sequestra it is mainly the carbonic acid, resulting from the metabolism of the tissues, which in the free state, together with the osteoclasts, dissolves the lime salts. The length of time occupied by the process of demarcation till the sequestrum has been completely separated varies greatly, and depends upon the size of the sequestrum and its location. The activity of the separating process in different individuals is also very variable. In general it may be said that extensive necroses, such as the total necrosis of a diaphysis, require in some instances from three to five months, and in others from eight to ten to twelve months, before they are completely separated. Separation of the sequestrum takes place more rapidly in young than in old patients.

Hand in hand with the separation of the dead portion of bone its regeneration proceeds by reactive bone formation—i. e., by an ossifying periostitis and osteomyelitis—as in the repair of fractures. Through the action of the periosteum a capsule of bone—the involucrum, as it is called—is formed around the sequestrum, as in the case of necrosis of the entire diaphysis (Fig. 353, *b*, and Fig. 354, *b*). The fistulæ which lead from the involucrum to the surface of the body are called cloacæ, an expression which has passed out of use at the present time. Through these cloacæ, or, better, fistulæ, the pus escapes from the cavity containing the sequestrum (Fig. 353, *a*, and Fig. 354, *a*). Large defects develop especially in those parts of the involucrum where the periosteum has perished in consequence of suppuration or a traumatism. In cases of central necrosis—i. e., necrosis in the interior of a bone—the innermost layers of the involucrum are, of course, formed from portions of the old intact bone. But even in these central necroses there usually occurs a reactive ossifying periostitis with the formation of fresh layers of bone. The capabilities of regeneration possessed by bones (a subject which has been thoroughly investigated by Ollier) are in general very great, and a necrosis which involves the whole of a long bone can be so completely compensated for that no variations from the normal will be

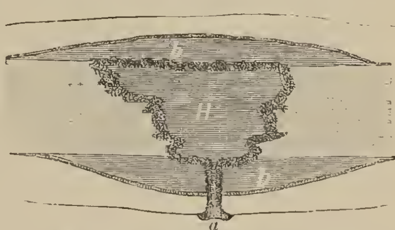


Fig. 354.—Partial necrosis of a hollow bone: *H*, cavity in the bone after removal of the sequestrum; *a*, fistula; *b*, newly formed bone or involucrum (schematic).

noticed. But occasionally the regeneration is defective, or may even be entirely absent and permit the defect to persist. Not infrequently, in the case of a necrosis involving the diaphysis of a long bone in a young subject, there will be observed, in consequence of the irritation of the epiphyseal cartilages, an increased longitudinal growth causing the bone in question to become two to three centimetres longer than the corresponding one on the sound side.

Various Kinds of Necrosis Distinguished by their Location and Extent.—According to the situation and extent of the necrosis we recognise a superficial, external, or peripheral necrosis in contradistinction to the above-mentioned central necrosis occurring in the interior of a bone. We also recognise a partial and a total necrosis, and a multiple necrosis occurring in different portions of the same bone or in several bones of the same skeleton. The necrosis tubulata (Blasius) with a tubular-shaped sequestrum is very rare; the internal axis of the sequestrum is formed of living bone substance which is firmly connected with the old bone. Consequently we have to deal with tubular sequestra in which there is a preservation of the innermost layers of bone or a considerable regeneration of the latter by an ossifying periostitis.

Symptomatology and Diagnosis of Necrosis.—The symptoms caused by necrosis have already been partly described. They are mainly due to the demarcating inflammation and regenerative new formation of bone for casting off and replacing the dead portion, which come more and more into prominence after the subsidence of the primary disease (periostitis, osteomyelitis). If there has been a loss of substance in the overlying soft parts the dead bone will be plainly visible; but if the necrotic bone is covered by soft parts, and if the sequestrum is deeply situated, the bone will ordinarily be found to be evenly thickened at the affected point, as a result of the ossifying periostitis (Figs. 353, 354). The presence of fistulous tracts, which usually discharge only a little pus, is another symptom of necrosis of bone. If a metal probe is passed through these fistulous passages it will usually strike the surface of the sequestrum. The latter feels hard, and if percussed with the probe emits a tympanitic sound. In the case of superficial or total necrosis the surface of the sequestrum is smooth; if the necrosis is central the surface is rough. The dead bone is also recognisable by its lack of blood, and by its white colour when compared to the rosy appearance of the living bone. It is very important, both for diagnosis and treatment, to determine whether the sequestrum has become movable. The mobility of the sequestrum can be ascertained by pressing the probe firmly against it, or by passing two probes through two different fistulæ down to the sequestrum,

or finally by attempting to move it back and forth by means of a dressing forceps. Occasionally a sequestrum which has become entirely free is so tightly enclosed that it is impossible to demonstrate its mobility. In such cases the separation of the sequestrum is determined by the duration of the disease. Necrosis may be mistaken for those central bone diseases which lead to enlargement of the bone with the formation of fistulæ, such as central bone abscesses and tumours of bone, and then particularly for caries. The typical caries, with few exceptions, as we saw, is a tubercular process, and is very often combined with necrosis. The tubercular sequestra usually contain cheesy tissue and have a soft feeling, while the sequestra of ordinary necrosis appear white and hard, like normal bone. The pus in necrosis is scanty and more mucoid, but in caries it is a thin liquid mixed with cheesy masses. The fistulous tracts of tuberculosis generally have a pale, lardaceous appearance, and if a probe is introduced through them it strikes against soft, crumbling bone; while in necrosis the granulations usually have a vigorous, healthy appearance and bleed easily, and the sequestrum when touched by the probe feels hard. Furthermore, the development of the two diseases is different. The tubercular caries begins gradually, and mainly affects the epiphyses and the spongy bones, while the typical necrosis ordinarily develops after acute or subacute inflammation of bone, especially the long, hollow bones (femur, tibia, humerus).

Treatment of Necrosis.—The treatment of necrosis before the sequestrum has separated is purely symptomatic, and consists mainly in keeping the fistulæ clean. When the sequestrum has become completely free it must be removed by operation, if it has not already been spontaneously cast off or out. Even large, deeply located sequestra can work their way outwards through the cloacæ and come to lie beneath the skin, which they then gradually penetrate. I extracted simply with the fingers, in the case of a twelve-year-old boy, a large, completely separated sequestrum consisting of the entire thickness of the femur. During many months it had projected several centimetres from the soft parts, and no one had dared remove it. As a rule, only those sequestra which are completely free should be removed, but there are a few exceptions to this. In the case of phosphorus necrosis, for instance, the foul suppuration compels us to adopt operative measures before the sequestrum has become completely separated, and early resection—i. e., early removal of the primary focus of disease—should be undertaken to shorten the process and to prevent it from extending further. If the disease is left to itself, the entire lower jaw perishes, according to Häckel, in seventy-nine per cent. of the cases. In ordinary

necrosis we must wait for the separation of the sequestrum to become complete, for the reason that the loss of substance will have been replaced by a new formation of bone, and that if we operate before the separation is complete we are liable to remove too much of the healthy bone, or possibly too little of that which is dead. In doubtful cases, where the mobility of the sequestrum cannot be determined, the length of time the process has lasted must be taken into consideration in deciding whether or not operative removal of the sequestrum should be undertaken. On the other hand, when the necrosis is extensive, though the sequestrum be free, the operation should be postponed if the new formation of bone is too scanty.

The Operative removal of the Sequestrum (Sequestrotomy).—If the necrosis is not encapsulated, the fistulæ are simply enlarged to the necessary amount with the knife and the sequestrum extracted with suitable forceps, such as a dressing forceps. If the sequestrum is encapsulated by an involucrum, the latter must be opened with the hammer and chisel after freely dividing the soft parts and elevating the periosteum. Esmarch's artificial ischæmia should be used for the extremities. After extraction of the sequestrum the cavity in the bone should be thoroughly scraped out, and then either packed with iodoform gauze, or the wound in the soft parts closed almost entirely by sutures, after providing for drainage. If the wound is left to granulate, the skinning-over process can be hastened later on by the transplantation of skin. Schede's method of obtaining healing under an aseptic blood-clot (see page 102) is also good—i. e., the wound in the soft parts is closed by sutures without drainage, though I leave one angle open as a means of escape for any surplus accumulation of fluid. To prevent recurrences and to obtain speedy recovery, the involucrum should be removed, as Riedel rightly says, until only a wall of cortex remains in the form of a flat trough. If the operation has been performed under Esmarch's artificial ischæmia, antiseptic dressings exerting pressure should be applied, and the extremity elevated, before the rubber tourniquet is removed; the limb should then be kept elevated for the next twelve to twenty-four hours. It is very important that the extremity which has been operated upon should be immobilised as much as possible by a splint. If fistulæ persist, they must be thoroughly scraped out, and the sequestrotomy, when necessary, repeated for the extraction of any other sequestra which may be present. Sequestrotomy is a very beneficent and not at all a dangerous operation if performed with antiseptic precautions.

Lücke and Bier have recommended an excellent new method for sequestrotomy which is called osteoplastic necrotomy (Fig. 355). In

the first place, the incisions *a c*, *a b* and *c d* are made through the soft parts, then the bone, which in Fig. 355 is the tibia, is cut half through transversely with a keyhole saw and divided with the chisel in the line of the longitudinal incision. By depressing the handle of the chisel the skin-periosteal-bone flap thus fashioned is broken through along the line where it still remains joined to the rest of the cortex, and is turned back like the lid of a box, exposing the cavity containing the sequestrum (see Fig. 355). After removing the sequestrum and scraping out and disinfecting the cavity, the cover is replaced, and the wound in the soft parts closed immediately or by secondary sutures applied after the wound has first been packed. Recovery usually takes place with slight suppuration.

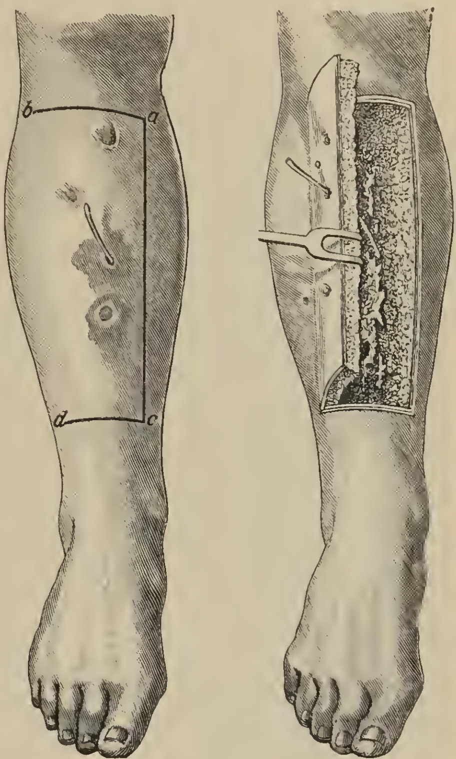


FIG. 355.—Osteoplastic necrotomy.

§ 107. **Spontaneous (Inflammatory) Separations of the Epiphyses.**—The spontaneous (inflammatory) separations of the epiphyses which occur in the bones of young subjects at the cartilaginous junctions with the diaphyses have already been discussed under the subject of Suppurative Periostitis and Osteomyelitis. As a matter of fact, the spontaneous separation of an epiphysis from the bone is almost always secondary to suppurative inflammation of the periosteum, the marrow of the bone, or the joint. But occasionally the epiphyseal separation is due to primary inflammation at the cartilaginous symphysis, as, for example, is the case in the osteochondritis luetica occurring in the course of syphilis. Multiple epiphyseal separations affecting several bones have been observed in pyæmia. The non-suppurative, spontaneous epiphyseal separation is very rare, and when it does take place may be due, according to Poupart, Petit, and Volkmann, to a hæmorrhagic malacia of the epiphyseal cartilages occurring in scurvy.

The osteochondritis dissecans described by König, the nature of which is obscure, also sometimes leads to complete separation, for example, of the head of the femur from its neck, without any traumatism having been received, and even occurs in people from thirty to forty years of age.

According to Volkmann, the typical spontaneous separation of the epiphysis is generally observed before the fifteenth year, and no case has been recorded where it happened later than the twentieth year. It is well known that the cartilage between the epiphyses and diaphyses persists till about the twentieth to twenty-second to twenty fourth year of life, the epiphyses joining with the diaphyses somewhat earlier in women than in men. Separation of the epiphysis is most common at the lower end of the femur and the upper end of the tibia.

Tranmatic separations of the epiphysis are described on pages 575 and 589.

The symptoms of epiphyseal separation are in the main those of a fracture, and repair takes place in precisely the same way. We have discussed on page 589 the occurrence of disturbances of growth after bony consolidation of the epiphyseal line. It need only be briefly stated here that in two cases of suppurative separation of the upper epiphysis of the tibia in comparatively young children, Blasius and Volkmann were able subsequently to demonstrate no shortening after the growth of the body had been completed.

The treatment of separations of the epiphyses is conducted according to the rnles which govern the treatment of simple and compound fractures, and is the same as that for traumatic separations, which was given in § 101.

§ 108. **Rhachitis.**—Rhachitis (from *ῥάχις*, the spine) is a general disturbance of nutrition which occurs in early childhood, and anatomically is characterised mainly by the formation of bone which is deficient in lime, and by an increased absorption of bone. Therefore the bones affected by rickets are abnormally soft and have a tendency to bend, to suffer infractions ; and the epiphyseal cartilages are remarkably thick—a peculiarity which has given the disease the name of *doppelte Glieder* (donble limbs). Rhachitis is a disease affecting the development of bone, and a trne disease of childhood, most commonly beginning in the first or second year of life, very rarely after the fifth or sixth. According to Schwartz, pronounced rickets is often observed in infants, and the investigations of Kassowitz show that it frequently begins during the latter months of fœtal life, in consequence of the transmission of morbid stimuli, or as a result of deficient absorption of lime from the maternal circulation, and then during the months imme-

diately following birth the symptoms of the affection become more and more marked. In the Vienna obstetrical clinic, among five hundred children, Schwartz found 80·6 per cent. to be rhachitic, and the great majority of the mothers of these rhachitic children had lived under improper dietetic and hygienic conditions, and during their pregnancy had done hard work. Rhachitis was first accurately described by the English surgeon Glisson in the middle of the eighteenth century—hence the name "English disease"—but it was known to the ancients.

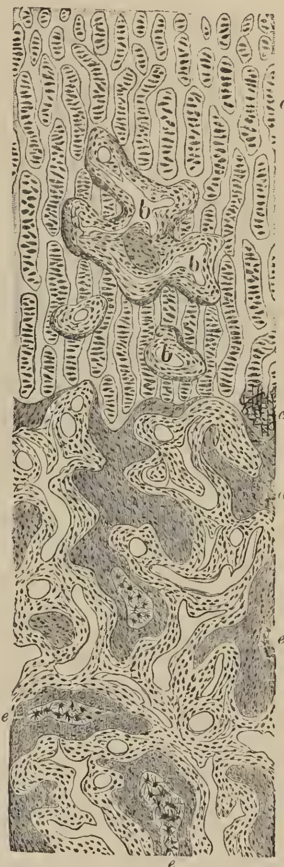


Fig. 356.—Rhachitis. Longitudinal section through the upper epiphysis of the tibia near the boundary of ossification; *a*, zone of the proliferating columns of cartilage; *b*, vascular medullary spaces in the cartilage; *c*, calcified cartilaginous tissue; *d*, osteoid uncalcified or only slightly calcified tissue with remnants of cartilaginous tissue; *e*, fully formed bone.

Anatomical Changes in Rhachitis.—The anatomical changes in rickets have recently been studied by Virchow, Kassowitz, Baginsky, and others. Kassowitz ascribes all the manifestations of rhachitis to chronic inflammatory changes at the boundary line between the fœtal and infant bone—i. e., to an abnormally increased vascularisation of the tissues which go to form bone. As a result of this hyperæmia, and the numerous, chiefly new-formed vessels at the epiphyses in the periosteum and medulla, there occurs a growth of the epiphyseal cartilages, a diminished deposit of lime salts, and an increased resorption of the fully formed bone. The bone undergoes a lacunar absorption (Fig. 343), osteoclasts being present, and, as I have stated before, is probably dissolved by carbonic acid. Rhachitic bone is poor in lime, and the newly formed bone remains for a long time in the uncalcified state. Not till the rhachitis has run its course does the ground substance of the bone become completely calcified, and then usually to an extreme degree, so that the affected bone appears thickened and very hard—sclerosed. The changes at the epiphyses are very characteristic. Under normal conditions the epiphysis is defined by a plain white line, cartilage and bone being sharply differentiated from one another. But in rhachitis this sharply defined linear boundary is absent, and the different tissues,

the cartilage, bone and medulla, appear as though blended together without any system (Fig. 356). The cartilaginous epiphyseal line is broadened and irregular, the boundary between cartilage, bone, and medullary tissue is not well marked, and the zone of calcification at the points of ossification is absent or deficient. The most important factors in the process are always the insufficient deposit of lime salts and the increased absorption of the bone already present. Baginsky states that rhachitic bone has lost more than three fourths of the lime it contains. Rhachitic bones are so soft that they can easily be cut with a knife, and, in consequence of this softness, deformities of the skeleton occur. In older children the changes in the thorax, the vertebræ and extremities are more prominent than those in the skull. Bow-shaped curves develop in the bones of the extremities, or, more commonly, angular deformities at the ends of the diaphyses (Fig. 357) with thickening of the epiphyses. The joints are loose, abnormally movable, and painful. At the knee joint, for instance, there is very often a considerable abduction or adduction and rotation of the leg in consequence of the relaxation of the ligaments of the joint and the rhachitic curvature which exists in the tibia and femur (genu valgum and genu varum rhachiticum). At the hip joint the rhachitic bending of the neck of the femur is to be noted. In the foot the so-called "flat foot" develops, etc. This relaxation of the joints and softness of the bones are the reasons why rhachitic children take so long to stand and walk, and why they lose their ability to perform these acts in recurrent rhachitis or rhachitis of late development. The pelvic walls fall together, causing the cavity to become contracted, the promontory of the sacrum projects downwards and forwards, the acetabular region is pushed inwards, the symphysis forwards. Curvatures develop in the vertebræ (scoliosis, kyphosis), and the thorax, particularly at the points where the ribs join the costal cartilages, becomes depressed, so that in severe cases the sternum is pushed forwards (the so-called "chicken breast," or pectus carinatum). In the skull, especially in the occipital region, the bones remain for a very long time soft and yielding to pressure, and, as a result of the loss of bone substance, some portions may again become membranous (cranio-tabes rha-

Fig. 357.—Rhachitic deformities of the leg.

chitica). The cutting of the teeth is delayed, and after the disease has been cured they often come through precipitately. The longitudinal growth and body weight are less than they normally should be. Bouchat states that rhachitic children only grow about two to three centimetres in a year, while the average longitudinal growth in health amounts to about seven to eight centimetres.

Under anomalies of internal organs are to be mentioned disturbances of the central nervous system and of the circulatory and digestive organs, such as, for example, hypertrophy or sclerosis of the brain, and chronic hydrocephalus. The spasm of the glottis, which is so common in rhachitic children, is probably caused by a general or a reflex anæmia. Disturbances of digestion (dyspepsia, diarrhœa, alternating with constipation), chronic bronchitis, lobular pneumonia, etc., are very common. The liver is very often decreased in size; the spleen, on the other hand, is usually but not always enlarged, and sometimes attains enormous dimensions. The skin, mucous membranes, lymph glands, etc., often show the same disturbances of nutrition as in scrofula (see page 423). In the form of rhachitis appearing somewhat later in life (rhachitis tarda), Levrat (Lyon) very often observed goitre.

Analyses of the urine show, according to Baginsky, that (1) a healthy child retains more nitrogen in its system than a rhachitic one, and excretes phosphoric acid more freely in the urine; (2) that under the influence of dyspeptic conditions the rhachitic child excretes nitrogen in the urine more readily than the healthy child, and retains phosphoric acid; (3) that no difference can be made out between healthy and rhachitic children as regards the excretion in the urine of lime and magnesium; (4) that the relative amount of chlorine excreted in the urine of healthy children is greater than in that of rhachitic children. As regards the excretion of phosphorus or phosphoric acid in the urine of rhachitic children, the statements of authorities vary very greatly; but as a general thing the majority of German authorities declare that there is a diminution of the phosphoric acid in the urine (hypophosphouria) in rickets; while the majority of French authorities maintain that there is an increase (hyperphosphouria).

The analysis of the ash of the fæces shows that more lime is excreted in the stools of rhachitic children (to one kilogramme of body weight) than is normally the case, and that the excretion of phosphoric acid, as compared with that in health, is not increased.

The Etiology of Rhachitis.—The cause of rickets—which we have learned to recognise as a general disturbance of nutrition in children, mainly localised in the bony system—has been made the object of

much experimental investigation. The majority of the authorities ascribe the cause of rhachitis to malnutrition. As a matter of fact, we know that a proper supply of the salts of the alkalies and of the earthy salts is of the greatest importance for the nutrition of all the tissues. Chossat and others have demonstrated by experiments on young growing animals that by feeding them with food deficient in lime, young birds and dogs, for example, show changes which are analogons to those in rhachitis. Baginsky, whose careful investigations include 627 cases of rickets (347 boys and 280 girls), also states that the disease is a result of unfavourable conditions of life, especially deficient nourishment, bad dwellings, etc. Rhachitis is, in fact, a disease of the poor, particularly in large cities, and occurs less often in the country, as Morgan and Baxter have recently proved by extensive statistics. Billroth and Winiwarter maintain that in Vienna about eighty per cent. of the children of the poorer classes show symptoms of rickets. Children who are brought up by bad artificial feeding without being nursed at the breast, and who have disorders of digestion, are particularly apt to be affected with rickets. According to R. L. Lee, preceding respiratory disturbances due to bronchitis, pneumonia, whooping-cough, etc., are also of great etiological importance. Furthermore, we saw on page 629 that the syphilitic poison, and possibly also other hæmatogenous dyscrasiæ, excite changes at the epiphyseal junctions which are similar to those of true rhachitis; and doubtless rickety children suffer from hereditary syphilis more often than is generally supposed.

The Course of Rhachitis is for the most part chronic, more rarely acute, and the earlier the rhachitis occurs the more rapid, as a general thing, is its course. Thus the rare cases of congenital rickets run a very rapid course; and of the children affected by the disease during the months immediately following birth, a large part perish from increasing inanition due to unfavourable hygienic conditions. But if the causative factors are removed, and the children properly fed and their surroundings improved, the disease usually disappears rapidly—in the milder cases within five to six months, and in the more severe ones within two to three years. Occasionally the disease drags on till the fifth or sixth year; cases lasting longer than this are very rare. In the cases of *acute* rhachitis there are sometimes complicating disturbances of nutrition, particularly scurvy, which may occur simultaneously with the rickets (Th. Smith, Barlow, etc.).

The Diagnosis of Rhachitis, as a rule, is very easy, for the reason that the above-described anatomical changes in the skeleton are pathognomonic. It should be a rule, in making an examination, to undress completely all children suffering from chronic disease.

The Prognosis, if proper treatment is adopted, is favourable, as we have said before. But if the unfavourable conditions continue, a large proportion of rhachitic children perish from diseases of the intestinal tract, of the respiratory organs, from hydrocephalus, general inanition, etc.

The Treatment of Rhachitis consists, in the first place, in the administration of proper food to the child, and in doing away as soon as possible with all unfavourable hygienic conditions. Inasmuch as recent investigations show that rhachitis is of such common occurrence in young infants, they must always be carefully examined for its presence, and in cases where the disease is found the proper treatment must be begun early. The best food for suckling children is mothers' milk or good cows' milk sterilised by Soxhlet's apparatus. Nursing the child longer than the first year of its life, Baginsky states, is just as apt to cause rickets as is the administration at too early a period of starchy or indigestible food. All disorders of digestion and other complications in rhachitic children should be carefully treated according to the general rules which apply to them. Internally, cod-liver oil, iron, lime, phosphorus, arsenic, and pyrogallic acid have been recommended for rhachitis, but in their administration the state of the digestive organs must be taken into consideration. Cod-liver oil, which may be combined with extract of malt, is useful for children who are not fat, especially in winter. Lime is given in the form of liquor calcis added to milk, or in a mixture made of carbonate and phosphate of calcium with ferri oxyd. sacch. (ferri carb. sacch.), equal parts of each, enough to cover the point of a knife, three times a day. On account of its osteoplastic action the administration of phosphorus has recently been recommended for rhachitis by Wegner and Kassowitz. It is given (1 milligramme *pro die*) in cod-liver oil (0·01 gramme phosphor., 1000 cubic centimetres ol. morrhuæ, one to two teaspoonfuls a day), or in pill form with oil of phosphorus and some indifferent powder enclosed in gelatine capsules. Maas and others maintain that arsenic and pyrogallic acid have also an osteoplastic action like phosphorus. Three per cent. brine baths, sea baths, health resorts situated on high land, and proper climate have as valuable an influence upon rickets as they have upon scrofula (see page 424). To prevent as far as possible the curvatures and angular deformities which may occur in the extremities, for example, rhachitic children should not be encouraged to stand and walk at too early a period. Braces and similar apparatus should be used to support the lower extremities, and the application of light water-glass or starch dressings is also advantageous. After the rhachitis has subsided, the bony deformities, particularly those in the leg, often have to

be corrected, the crooked bones either being broken by hand or by Rizzoli's osteoclast (Fig. 74, page 84), and then when they have been rendered straight treated like a subcutaneous fracture. In other cases, when the strength and sclerosis of the bone is considerable, it will be impossible to break the bone subcutaneously, and subcutaneous osteotomy, combined possibly with an excision of a wedge-shaped piece of bone, must be undertaken. To perform osteotomy, the proper incision is made through the skin, and through this the bone is divided with the hammer and chisel, with the exception of a small portion of the cortex, which is then usually broken by hand. The wound is not sutured, and after covering it with an antiseptic protective dressing a plaster-of-Paris splint is immediately applied. If the operation is carried out with antiseptic precautions it is entirely devoid of danger. Macewen's osteotomy at the lower end of the diaphysis of the femur is also very appropriate in cases of genu valgum rhachiticum. Tenotomy of the tendo Achilles must sometimes be added when the curvature of the tibia is convex anteriorly. But frequently braces will be sufficient to overcome deformity, the bones gradually becoming straight of their own accord. I must refer the reader to my Special Surgery for the particulars of the treatment for the various sequelæ of rhachitis in the different portions of the body, such as the vertebræ, the extremities, etc.

§ 109. **Osteomalacia.**—By osteomalacia we understand a peculiar softening and resorption of bone substance which is observed most commonly in women during pregnancy and the puerperium, less often

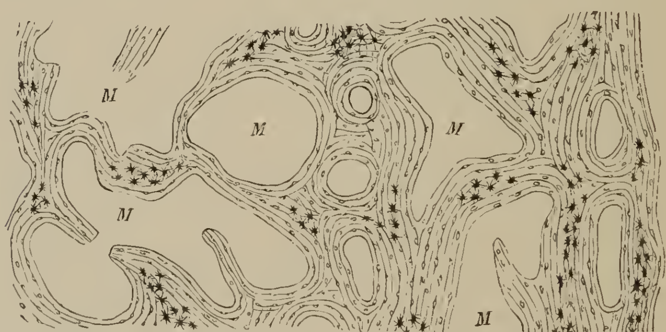


Fig. 358.—Osteomalacia (pelvis). Trabeculæ of decalcified bone with remnants of calcified bone. The enlarged medullary spaces (*M*) have arisen from absorption of the trabeculæ. × 75.

in men, and in women who are not pregnant. The disease not infrequently occurs in pregnant and milch cows. In osteomalacia the normal, strong bones of adults become soft, while in rhachitis, on the other hand, we have to deal with a disease of development affecting

young bone, in consequence of which the latter remain soft and do not become firm.

Anatomical Changes in Osteomalacia.—The puerperal form of osteomalacia probably always begins in the pelvis, and either remains limited to the latter or attacks other bones, and may even involve most of the skeleton, particularly if the woman passes through several pregnancies after the appearance of the disease. The non-puerperal form begins most commonly in the vertebræ and thorax, and then extends to the extremities and finally to the bones of the head. The softening, the absorption of bone substance (Fig. 358), is an halisteresis—i. e., the lime salts are first dissolved, but the decalcified ground substance persists a little while longer, then it also gradually disintegrates, and is finally absorbed. The absorption of the lime salts always begins in the periphery of the bone and advances steadily towards the centre. In this manner a considerable loss of bone may be brought about, and the cortex of the long bones may become as thin as paper, or the diseased bone may even entirely disappear, leaving only the periosteum and medulla to persist as an elastic tube. Morand observed a very pronounced degree of osteomalacia in a woman who possessed in the place of most of her bones only membranous cylinders or very thin tubes of bone. In the milder cases, which recover quickly, the decalcified bone substance can be very rapidly changed to normal bone by a fresh deposit of the salts of lime. As long as the disease is advancing the medulla is usually very richly supplied with blood, contains numerous hæmorrhagic foci scattered through it, has an abundance of cells, and is poor in fat. In rare instances of osteomalacic softening of bone there have been noted multiple cystic formations with tumour-like enlargement of the softened portions of bone (Albertin). There are, moreover, cases which present the clinical picture of osteomalacia, and anatomically are due to the development of multiple true tumours, especially sarcomata (Recklinghausen). As a result of the softening of the bones there of course arise corresponding curved or angular deformities, and fractures. Changes of shape in the osteomalacic pelvis are particularly common. Recklinghausen and Rehn have recently described an infantile osteomalacia, but this is probably in the main a severe rhachitis.

The Etiology of Osteomalacia.—The precise cause of osteomalacia is still but little understood, though various theories have been advanced. We only know that it occurs chiefly in pregnant or nursing women and animals, and is common in certain regions which in Germany lie along the Rhine, while other places, like the valley of the Oder, appear to be free from it. Damp, unhealthy dwellings, malaria, anæmia, and other constitutional anomalies connected with disturbances of nutrition, are said to be of importance. Cohnheim maintains that osteomalacia, like rhachitis, is a disturbance of nutrition, and he believes that the maternal organism during pregnancy and the nursing period contains too little lime, because a very large amount of lime salts are necessary for the development of the fœtal skeleton as well as for the milk. For

this reason only osteoid tissue, which is deficient or entirely lacking in lime, is formed in the maternal organism. Consequently, according to Cohnheim's theory, the uncalcified or deficiently calcified bone tissue is not decalcified *old* bone tissue, but new-formed osteoid tissue. I believe, however, that the old idea is correct, viz., that the bone tissue which is poor in lime or in which the lime is absent is the decalcified ground substance of the old bone. It is natural that the cause for the decalcification in this condition should also be ascribed to an acid such as lactic acid, or, more correctly, carbonic acid; but as yet no proof of this has been obtained. Heiss and others have fed animals with lactic acid for months (three hundred and eight days, for example), and yet have not been able to produce osteomalacia. It seems more probable that the decalcification is due to the action of carbonic acid; it is possible, and the hyperæmia of the medulla favours this view, that in osteomalacia we have to deal with an inflammatory process accompanied by an increased vascularity and an abnormal formation of carbonic acid. Examination of the urine, however, does not always show an increased excretion of earthy phosphates, a thing which the acid theory would lead us to expect. Petrone calls attention to the increased amount of nitric acid contained in the urine, and believes that osteomalacia is caused by the micro-organism described by Schlössing and Münz, which produces nitric acid. In one case of non-puerperal osteomalacia observed by Kobler, with pronounced changes in almost all the bones, examination of the ash obtained from the blood revealed a considerable increase of sulphuric acid and a diminution of the sodium to less than half the normal quantity. The rare osteomalacia of men, and of women who are not pregnant or nursing, depends, according to Cohnheim, in the main upon disorders of digestion or of assimilation, combined with a lessened absorption of lime.

We have practically given the symptomatology of osteomalacia in the above description. The disease almost always begins, as we have said, during pregnancy or during the puerperium, with severe shooting pains in the affected bones. Consequently the disease, at the outset, is often confused with rheumatism, until the changes in the shape of the bones enable the correct diagnosis to be made. The affection may become very pronounced during a single pregnancy or a single puerperium. The milder cases will get entirely well; but very frequently the disease makes pauses in its progress, and then, in conjunction with another pregnancy, though apparently cured, it will break out again with fresh intensity. Recklinghausen observed osteomalacia in young subjects in combination with Basedow's disease.

The *prognosis* of osteomalacia is very unfavourable, and actual cures

are exceedingly rare. Nevertheless, the operative removal of the ovaries in puerperal osteomalacia, recently recommended by Fehling, yields surprisingly good results.

The *treatment* of osteomalacia is like that of rickets (see pages 643, 644), and consists primarily in the administration of good nutritious food, also cod-liver oil, iron, lime, quinine, phosphorus, and arsenic. All unfavourable hygienic conditions, disturbances of nutrition, and constitutional anomalies are, as far as possible, to be done away with. If the woman is nursing her child, she must be forbidden to do so, and made aware of the danger that in a new pregnancy the disease may recur with increased severity. Great interest attaches to the cures of osteomalacia recently obtained by the removal of the ovaries. The castration, which was first recommended by Fehling, is either performed by itself, or combined with Porro's supravaginal removal of the gravid uterus. The success of this procedure is so remarkable that patients with a very pronounced form of the disease can be cured and allowed to attend to their employment after the lapse of from three to four to five weeks. Petrone believes that the success is mainly to be ascribed to the narcosis and not to the operation, as he has cured one case of osteomalacia in three weeks by the daily administration of two grammes of chloral hydrate, the nitric acid which was present in the urine disappearing on the fifth day of the treatment.

The castration recommended by Fehling for osteomalacia, with or without supravaginal removal of the uterus, deserves the most general consideration because of the success which has already been obtained. We must not omit to state that in rare instances the osteomalacia of women also gets well spontaneously.

§ 110. **Atrophy and Hypertrophy of Bone.**—Atrophy of bone is due to various causes. Every resorption of fully formed bone substance, which, as we have seen, occurs so frequently under pathological conditions, is to be looked upon as an atrophy of bone. The resorption of bone substance either takes place on the external surface of the bone or it starts in the medulla and advances outwards. In the outer (concentric) atrophy the bone becomes smaller and thinner, while in the case of the internal (excentric) atrophy the medullary cavity and the Haversian canals grow larger and the bone becomes porous (osteoporosis).

The *senile atrophy* which affects the bones of the skull (the cranial vault, the inferior maxilla, etc.) and of the extremities, especially their articular ends, is a special form of bone atrophy. The senile osteoporosis of the neck of the femur is of practical importance, as the neck gradually becomes depressed and may be broken by a very slight traumatism.

A common cause of the atrophy of a bone is disuse of the latter (atrophy of disuse). We have said that this follows paralyses, inflammations of joints, temporary immobilisation of an extremity by a plaster-of-Paris dressing, etc. The disappearance of the acetabulum, which occurs when a dislocation of the hip is not reduced, also belongs to the atrophies of disuse. This form of atrophy may take place in certain limited portions of a bone, as in the callus formed after a fracture, those portions of the bone substance gradually disappearing which have become useless for the function of the bone.

FIG. 359.—Partial (tropho-neurotic?) atrophy of the skeleton (upper part of the body); pelvis and lower extremities are well-developed; thirty-five-year-old unmarried woman (Mosengeil).

Another form of atrophy of bone is the neuroparalytic and trophoneurotic, which occurs in conjunction with diseases of the nervous system, such as tabes, or as a result of changes in the trophic nerve fibres or afferent nerves, or in the trophic centres in the anterior horns of grey matter in the spinal cord (Fig. 359). A careful description of the trophoneurotic diseases of the bones and joints is given in § 117.

Local arrest of longitudinal growth is caused by diseases of the epiphyseal cartilages, such as inflammation or suppuration, or it may follow their ossification at too early a period or their removal in too extensive a resection, etc. Pressure, inflammation, and the development of a tumour may also lead to localised atrophy, to wearing away of bone, or to caries.

Hypertrophy of Bone is either limited to some particular portion of a bone, as in the formation of osteophytes, or it affects the entire bone, the whole volume of the latter being increased or only its length or thickness. The hypertrophies include the hyperostoses mentioned on a previous page—i. e., the increase in volume following periosteal and endosteal formation of bone, and the *osteosclerosis* or thickening of bone tissue, which is also called eburneatio ossis.

Helferich and others have, as we remarked before, increased the development of bone at a given point by artificial hyperæmia, produced, for example, by tying off the extremity with an elastic tourni-

quet drawn moderately tight on the proximal side of the point in the bone which is diseased. This procedure is worth trying in the case of fractures where the callus formation is delayed and insufficient, and in pseudarthrosis, and also to diminish shortening, etc. (see page 603).

Fig. 360.—Partial giant growth on the hand (Curling and Böhm).

The lengthening which bones may undergo in conjunction with irritation of the epiphyseal cartilages due to injuries and diseases of the diaphysis or neighbouring joints and soft parts, is also a matter of practical importance. As Ollier has demonstrated experimentally, an increase in the longitudinal growth of young bones is very easily brought about by stimuli of various kinds. This explains the occurrence of the increased longitudinal growth which takes place in conjunction with fractures, especially those which are compound and heal with marked inflammatory reaction, or which follows necrosis, osteomyelitis, large ulcers of the foot, and diseases of joints. Young bones which have been dislocated and not replaced take on increased longitudinal growth if they are freed from the pressure of the superimposed bone. Thus, for example, increased longitudinal growth of the radius takes place after dislocation of its head.

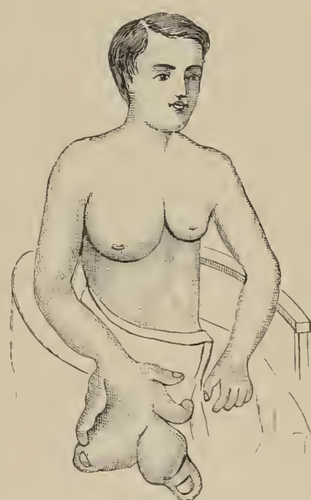


Fig. 361.—Giant growth of the upper extremity and the right side of the thorax (Wagner).

Congenital hypertrophy of bone makes its appearance in the form of *giant growth* of the fingers and toes (Fig. 360, macrodactylia), and also as giant growth of an entire extremity (Figs. 361, 362). According to Wittelshofer's statistics, all the cases of true giant growth hitherto recorded are congenital in origin, and originate, as in the case of the very considerable monstrosity illustrated in Figs. 361 and 362, from an abnormal increase of growth involving all the tissues of one part of the body. Giant growth is possibly a congenital trophoneurotic disturbance.

The cases of *acquired* hypertrophy of the bones and soft parts (compensatory hypertrophy) are, of course, to be distinguished from

this congenital giant growth. P. Wagner has recently collected several cases of congenital and acquired giant growth, and has given the literature on this subject (Zeitschrift für Chir., Bd. xxvi, page 216). Bessel-Hagen has called attention to the various anomalies of the bones and joints which occur in giant growth.

As regards the *treatment* of partial giant growth, elastic bandaging, massage, and Weir Mitchell's cure have been used with success in the

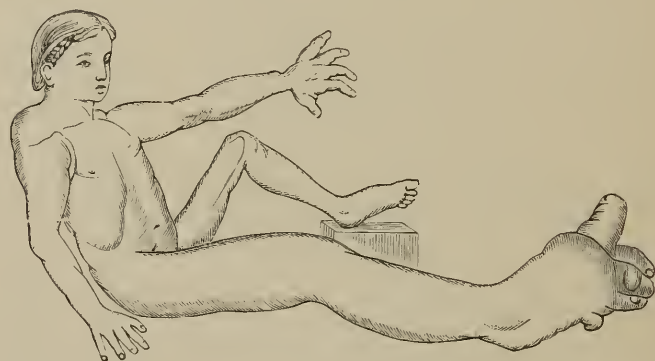


FIG. 362.—Giant growth of the lower extremity on the right side, and the upper extremity on the left side.

milder forms of the affection. In severe cases, which cause much trouble in consequence of the awkwardness and weight of the affected extremity, operative measures will sometimes be necessary, and the enlarged member should be removed (see also Treatment of Elephantiasis).

Acromegaly, a disease to which Marie, in 1886, first directed attention, must be carefully distinguished from the congenital giant growth. In acromegaly, which begins about the tenth to the twentieth to the thirtieth year of life, and lasts ten to twenty years or longer, there is a hypertrophy of all parts of the body, involving both the bones and the soft parts, especially of the head and extremities. The hands and feet have the appearance of paws. In the head the hypertrophy affects most commonly the lower jaw, tongue, under lip, and nose. The power of vision may be completely lost, owing to the pressure exerted by the enlarged sphenoid bone on the optic nerve. Hadden and Ballame state that the disturbance of sight is caused by compression of the optic chiasm or medullary striæ of the optic nerve brought about by the hypertrophy of the pituitary body. The vertebræ, sternum, and ribs are symmetrically enlarged; there are kyphotic curvatures of the spinal column; the joints are deformed; the internal organs, brain, muscles, nerves, etc., hypertrophy. The subjective

symptoms presented are pains in the head and joints, a feeling of weakness, and paræsthesia. A steadily increasing cachexia finally makes its appearance. The precise cause of acromegaly is still obscure. According to W. A. Freund, the affection is an anomaly of growth, and he believes that its immediate cause must be ascribed to an increased flow of blood to the dilated vessels. Inherited predisposition to the disease is contested by some authorities and accepted by others. It probably has a complex etiology, and occurs after various kinds of disorders, including tumours of the brain, for example. Great psychical excitement has frequently been thought to be the primary cause of the affection.

Acromicria.—The condition the reverse of acromegaly is called acromicria (Stembo, Reidel). In this there is a striking atrophy, especially of the terminal portions of the body (head, fingers, toes), together with a process of shrinkage, which attacks different organs and sometimes the entire body. The etiology of the affection is very obscure, and the disease must be carefully differentiated from syringomyelia, Morvan's disease, the anæsthetic form of leprosy, Raynaud's disease, and from analogous syphilitic or diabetic affections of the fingers. According to Stembo, the disease begins on the fingers. On the latter there is often a development of blebs or ulcers, which heal slowly, and are accompanied by intermittent pain. The skin on the fingers grows more and more thin, cicatricial, and tense; all the nails perish, the fingers become shorter and less movable, and the entire body grows smaller, from atrophy of the skin and the soft parts, including the tongue and œsophagus. The face assumes a peculiar stiff, immovable, and bird-like expression. There are no disturbances of sensibility, the cutaneous reflexes are normal, the tendon reflexes diminished, and the electrical excitability of the muscles and nerves is slightly increased.

Daily Variations in Height.—As regards the well-known fact that man becomes shorter in the course of the day, Merkel has made some accurate measurements (mostly upon himself), and has found that the length of the body in the morning in the recumbent position, immediately after awakening, is some five centimetres more than in the evening in the erect position. The loss in size is partly gradual and partly sudden. The former is due to the gradually increasing compression of the sole of the foot and the intervertebral fibro-cartilages; while the latter, or sudden diminution of stature on rising from the horizontal to the perpendicular position, is brought about by compression of the joints of the lower extremity, a shortening of eight millimetres taking place in the region of the ankle joint, of two to three millimetres at the knee, and of one centimetre at the hip. This lessening of the length of the lower extremities is mainly caused by compression of the elastic articular cartilages and by the sinking of the caput femoris into the cavity of the acetabulum, which occurs upon standing in the erect position.

Lymphadenia Ossium (Nothnagel).—A peculiar kind of pernicious bone disease, which has been described by Nothnagel, requires mention at this point. It was observed in a man twenty-four years of age, and terminated

fatally in a year and a half, the patient having been afflicted with severe pains, thickening of the bones, and steadily increasing cachexia. The autopsy revealed a very extensive development of a lymphadenoid tissue, with a great number of Charcot-Neumann crystals in the bones, and at the same time a periosteal and medullary new formation of bone. The medulla had almost completely disappeared. Nearly all the bones were diseased, the phalanges of the hands and feet and the bones of the face alone remaining unaffected. The lymph glands and the spleen were enlarged, probably to compensate for the lack of medullary tissue, with its power of making blood.

§ 111. **The Tumours of Bone.**—The tumours peculiar to bone (osteoma, exostosis, osteosarcoma, enchondroma, soft-bone tumours, cyst, etc.) will be described in §§ 125–130, where we shall take up the subject of tumours in general. At present we shall only briefly discuss the parasitic tumours of bone.

Of animal parasites there occur in bone the *echinococcus* and the *cysticercus cellulosæ*, the latter being very rarely met with. Volkmann mentions one case of Froriep's, in which this parasite was found in the first phalanx of the middle finger, the symptoms being those of a panaritium periostale.

Of echinococcus of bone there are fifty known cases.

Echinococcus of Bone.—The tænia echinococcus, as is well known, is a four-jointed parasite about four millimetres long, which lives in the intestinal canal of the dog; and only the cysticercus of this tænia, after the introduction of the tænia eggs into the intestinal canal, occurs in man. In whatever organs the embryo lodges, the liver being the one most commonly affected, characteristic cystic tumours develop. The cyst is made up of a lamellar, very elastic cuticular layer (ectocyst), on the inner surface of which is a granular parenchymatous layer. From this inner layer the so-called brood-capsules develop, and upon these are formed the scolices in great numbers. The echinococcus cyst either remains single—unilocular—or it goes on to form daughter cysts by exogenous and endogenous proliferation. The size of the cysts, especially in the liver, is often very considerable. The echinococcus multilocularis is another form of the echinococcus, which forms in the liver only small cysts in great numbers, varying from the size of a millet grain to that of a pea, which are surrounded by a thick, tough, diffuse mass of connective tissue.

The echinococcus cysts excite a local inflammation which leads to the formation of a connective-tissue capsule. The cysts, after attaining the size of a walnut or apple, often die, and their fluid contents become absorbed, a cheesy, fatty detritus or calcification being then found inside the shrunken sac. In other instances the cysts grow so large as to become dangerous, and by penetrating or bursting into some cavity of the body give rise to severe inflammations.

The echinococcus develops in bone, especially in the medulla (Fig. 363), and occasionally forms at some point where the bone has been sub-

jected to a traumatism. The echinococcus cysts of bone are of slow, indolent growth, and after the lapse of years sometimes give rise to painful tumours, which at the outset present the appearance of a central bone tumour and subsequently of a bone cyst. The affection occasionally remains latent for several years. Echinococcus cysts usually vary in size from that of the head of a pin to that of a pea, or they form large cysts (Fig. 363, *a*) which commonly break through the cortex after they have existed a long time, and invade the surrounding soft parts, muscles, vessels, and nerves, or neighbouring joint (see below). As Bergmann has remarked, there is sometimes a formation of abscesses in the tissues around the bone, which after being incised show no tendency to heal, and may lead one to suppose that there is a necrosis present. The pus at times is remarkably rich in cholesterin crystals, a fact which is of importance for the diagnosis. The atrophy of bone is not infrequently very considerable (Fig. 364). It is worth noting that, as Gangolphe says, the multilocular form of echinococcus of bone is by far the most common; it was found thirty-two times in thirty-seven cases, and only in five instances was encysted echinococcus present (which is much the more common form in the soft parts, especially in the liver). Of fifty-two cases, twenty-six were of the hollow bones (eleven humerus, eight tibia, six femur, one phalanx) and eighteen of the flat bones (eleven pelvis, four each involving the skull, scapula, and sternum, and the ribs once).

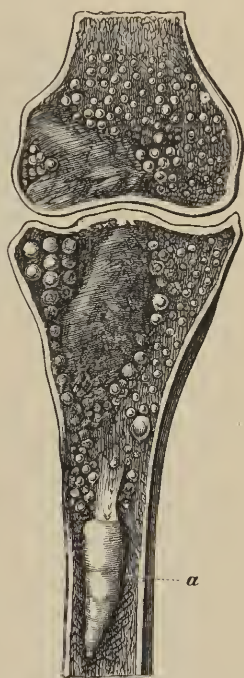


Fig. 363.—Echinococcus of the femur and tibia of a fifty-two-year-old woman: *a*, large echinococcus cyst. Amputatio femoris (Hahn).

The *diagnosis* can only be made with certainty when the soft, fluctuating tumours have broken through the bone, or when a portion of their contents can be withdrawn by an exploratory puncture. In the case of the long hollow bones the nature of the disease is occasionally revealed by the occurrence of a spontaneous fracture.

The *prognosis* is governed by the location of the disease, echinococcus of the bones of the skull and of the vertebræ and pelvis being the most unfavourable, while the echinococcus of the extremities is less so. Gangolphe states that out of seven cases of echinococcus of the vertebræ, six died of sepsis after the operation, while

of nineteen patients with echinococcus of the extremities only four died.

The *treatment* consists in as complete a removal as possible of the cyst as well as of the diseased bone, or, when this cannot be done, in incision, with destruction of the membrane by means of the sharp spoon, Paquelin thermocautery, etc. In the case of the extremities, amputation or disarticulation will often be necessary. Of the thirty-six cases of echinococcus of bone collected by Reszey and Hahn, twenty were operated upon, and of these fourteen were cured (two by incision, twelve by amputation). At all events the treatment should be as energetic as possible so as to prevent recurrences.

Fig. 364.—Echinococcus of the pelvic bones on the right side, with well-marked resorption of the bones of the pelvis and head of the femur of a twenty-five-year-old peasant woman (Viertel).

Echinococcus in Joints.—Occasionally, as we have remarked before, an echinococcus of bone breaks through into the neighbouring joint (Fischer found ten such cases in literature); but it is extremely rare for the parasite to lodge primarily in the joints. Of the above-mentioned ten cases, eight affected the hip joint, one the knee, and one an interphalangeal joint. Of echinococcus cysts of the pelvic bones with perforation into the hip joint, only one case has been cured by operation (Bardeleben). The treatment of this affection of the joints demands very energetic procedures (resection, or even amputation).

CHAPTER IV.

INJURIES AND DISEASES OF JOINTS.

Review of the anatomy of joints.—The acute inflammations of joints: Arthritis or synovitis serosa, sero-fibrinosa, and purulenta.—The acute polyarticular rheumatism.—The secondary inflammations of joints occurring in the course of acute infectious diseases (metastatic inflammations of joints).—Gonorrhœal arthrites.—The acute arthrites occurring in the course of syphilis.—Arthritis urica (gout).—Gout of lead poisoning.—Treatment of acute inflammations of joints.—The chronic inflammations of joints: Hydarthros chronicus.—Chronic articular rheumatism.—Chronic suppuration of joints.—The fungous (tubercular) arthrites, joint caries.—The syphilitic arthrites.—Arthritis deformans.—Diseases of joints in bleeders (hæmophilia).—Joint bodies.—articular neuralgias, articular neuroses (hysterical joint affections).—Neuropathic inflammations of bones and joints.—Anchyloses.—Deformities of joints (contractures).—Echinococcus in the joints (see page 654).—The injuries of joints: Subcutaneous injuries (contusions, sprains).—Dislocations (luxations) of joints.—Wounds of joints.—Appendix: Gunshot wounds.—Remarks upon military surgery.

§ 112. **Review of the Anatomy of the Joints.**—It is well known that the cavities of the joints of the cartilaginous skeleton of the fœtus are made by dehiscence, or softening and liquefaction of the formative tissue remaining between the cartilaginous layers. They develop later than the ligaments of the capsule, which, as processes of the perichondrium, stretch across the space lying between the ends of the cartilages. The articulations between the bones are commonly divided into two classes: the synarthroses and the diarthroses. The synarthroses are characterised by having a cartilaginous or fibrous layer interposed between the bone surfaces, which is connected to the periosteum, the latter extending from one bone to the other. In the diarthroses the continuity is completely interrupted, and they are provided with a loose capsule, which is generally strengthened by accessory ligaments. The inner surface of the capsule of a joint, or the so-called synovial membrane, is covered usually by a single layer of endothelium, which, as my investigations show, very often extends over the synovial fringes and interarticular ligaments as far as they lie free in the cavity of the joint, but under normal conditions does not, as a rule, cover the point of origin of the synovial membrane at the articular cartilage. In the

fœtus the cartilage is ordinarily partially covered by endothelium, and after birth, if a joint remains quiet for any length of time, the endothelium will grow over portions of the articular cartilages and other parts of the joint which present free surfaces. On the inside of the synovial membrane there are found thread-like outgrowths, the synovial villi (Figs. 365, 366), which can be seen especially well as floating structures when a joint like the knee is opened under water. Some of the villi contain vessels (Fig. 366), others do not; and some of them are single filaments, while others are branched and are provided with daughter villi. According to the nature of the tissue, cartilage villi, fibrous villi, fat villi and mucous villi can be distinguished, while between these individual kinds there are

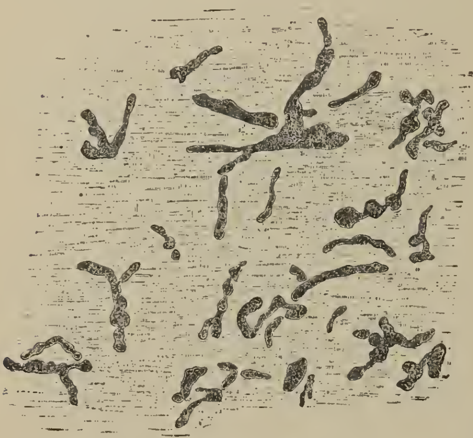


Fig. 365.—Synovial villi (knee-joint). Glycerin-osmic-acid. × 30.

Fig. 366.—Vascular synovial villi. Five per cent. bichromate of potassium. Knee-joint of man. × 30.

numerous transition forms. Cartilage cells are very often found in the fibrous villi.

FIG. 367.—Lymphatics of the synovial membrane (knee-joint of an ox). × 20.

The joint capsules are, as Fig. 367 shows, very richly supplied with lymph vessels—a matter of great practical importance. It is supposed that there are open communications—stomata, as they are called—between the lymph channels and the joint cavity on the inner surface of the articular capsule, as there are in other serous membranes; but as yet I believe no one has been able to demonstrate them.

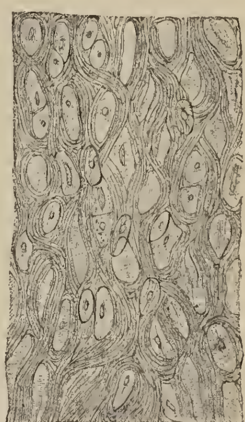


FIG. 368.—Hyaline cartilage treated in an incubator with trypsin. Network arrangement of the fibres. × 150.

The hyaline cartilage is only apparently homogeneous. As I was the first to show (Archiv für Anat. und Phys., 1877), it can be demonstrated by means of trypsin, or the prolonged action of permanganate of potassium, that hyaline cartilage is really made up of fibres which are bound together by a cement substance. The latter is dissolved by the above-mentioned materials, especially by the action of trypsin at a temperature of 38° to 40° C. (101·4° to 104° F.) in the incubating oven, and the fibres are then made evident (Figs. 368, 369, 370). They may have a lamellar arrangement, as in Fig. 369, or form a network, a reticulated structure (Figs. 368, 370). Through our knowledge that

even hyaline cartilage is constructed of fibres, we can more readily understand the various changes which occur, for example, in the calcification

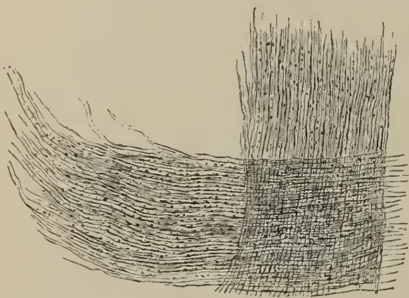


FIG. 369.—Hyaline cartilage treated in an incubator with trypsin. Arrangement of the fibres in the form of lamellæ. × 240.

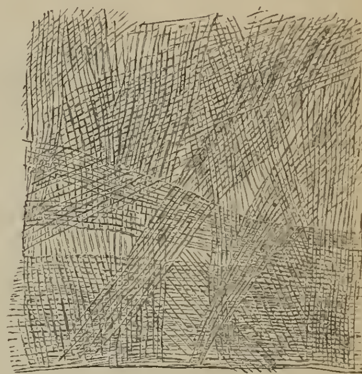


FIG. 370.—Hyaline cartilage treated in a hatching oven with trypsin. Network arrangement of the fibres. × 240.

of the callus or in the repair of wounds of cartilage, also the fibrillation of hyaline cartilage which takes place in chronic joint disease, etc. We have Budge to thank for his beautiful investigations upon the circulatory channels in cartilage.

The views of authorities vary as to the origin of the synovia, but my own investigations have led me to believe that it is mainly formed by the mucous and fat villi, partly by secretion and partly by a breaking up of their cellular elements. However, this is not the place to discuss any more fully the anatomy and physiology of joints, and I must refer the reader to the text-books on these subjects; but I have thought it wise to briefly touch upon some of the questions which are particularly important as regards the subject of diseases of joints. The mucous bursæ are described in § 99.

§ 113. **The Acute Inflammations of Joints.**—We distinguish, according to the nature of the exudate in the acute inflammations of joints, two general classes: the *serous* and the *suppurative* arthritis.

1. The *arthritis* or *synovitis serosa* (*hydrops articulorum acutus* or *hydarthros acutus*) is usually characterised by the presence of a cloudy, serous liquid containing a greater or less number of fine flakes of fibrin. If there is a considerable quantity of the latter present the arthritis is also called sero-fibrinosa. The other pathological changes which occur in a serous synovitis consist in a varying amount of hyperæmia and swelling, and upon microscopical examination there are usually found here and there small focus-like collections of leucocytes or extravasations of blood.

The *clinical course* of a serous synovitis is briefly as follows: If we suppose, for example, that the knee joint is the one affected, it is usually swollen and feels hot, is tender to the touch, and on palpation fluctuation is plainly made out, and the patella is lifted from its normal position—it "floats." Active and passive movements of the joint are possible, but cause pain. There is either no fever at all or only a very slight amount of it. The further course of the disease is in the main dependent upon the cause, but it is ordinarily favourable, and if proper treatment is adopted recovery will very speedily ensue. Occasionally an acute serous synovitis will change into the suppurative form or into a chronic hydarthros. Not infrequently after recovery from the acute hydarthros there is a pronounced tendency to relapses.

2. The *arthritis* or *synovitis acuta purulenta* (*empyema of the joint*) is characterised anatomically by the formation of a purulent or fibrino-purulent exudation. It either follows a serous or sero-fibrinous inflammation or begins as such. In addition to the pure or flocculent pus which is found in the joint, there is also usually present a marked swelling and hyperæmia of the synovial membrane and ligaments upon which a fibrino-purulent material is deposited, sometimes containing foci of pus. Furthermore, the articular cartilages become dull in appearance, and there is an even extension of the synovial membrane over their edges in the form of vascular, newly developed, delicate connective tissue. The milder grades of suppurative arthritis, without deep destruction of the synovial membrane, we shall designate as catarrhal suppuration of a joint. In the cases of longer duration, or in the more severe forms of suppuration, a suppurative panarthritis develops—i. e., all portions of the joint are attacked by the suppuration, the cartilage undergoes fibrillation and here and there becomes necrotic. The suppuration may extend to the bones and the medulla, and, after breaking through the capsule of the joint, give rise to periarticular abscesses, etc. In the worst forms of acute suppurative arthritis putrefactive changes take place, sometimes accompanied by a marked evolution of gas. Suppurative inflammation of a joint may terminate in a *restitutio ad integrum*, in recovery with partial or total stiffness of the joint (anchylosis), or in death.

The *clinical course* of an acute suppurative inflammation of a joint like the knee, is characterised by severe pain, by high fever, which often begins suddenly with a chill, by great swelling, and by pronounced disturbance of function. The knee is usually slightly flexed, and the least attempt at passive motion causes the most intense pain. The skin generally feels very hot, and is reddened. At the outset fluctuation is ordinarily not present, but becomes capable of

detection as the amount of pus increases. A characteristic feature of suppuration of a joint is the œdematous swelling of the parts surrounding it or of the entire extremity. The subsequent course of the disease depends upon the nature of the infection, and especially upon whether the suppurative arthritis receives early antiseptic treatment. If the joint is opened and drained antiseptically at an early stage, recovery with a movable joint may still be obtained; and even in neglected cases a *restitutio ad integrum* is possible with the help of antiseptics. In other instances the acute suppuration becomes chronic. Very often recovery takes place with more or less stiffness, or with partial or complete obliteration of the joint. When the joint is obliterated the granulation tissue which is present changes into cicatricial tissue—i. e., a cicatricial connective-tissue anchylosis develops, though sometimes the stiffness is due to bony union of the articular ends of the bones (*anchylosis ossica;* see § 118, Anchylosis). The worst cases terminate in death from pyæmia or septicæmia, the latter coming on with great rapidity in the case of putrefaction of a joint, unless operative measures are very speedily and energetically adopted.

Suppuration of joints in arthropathies is described in § 117, and the spontaneous dislocations which occur in acute inflammations of joints in § 122 (Luxations).

The contractures which take place in the course of acute joint diseases are mainly reflex in their nature (see pages 549 and 554).

The Primary Acute Suppurative Synovitis of Small Children.—Krause has recently described a primary acute suppurative synovitis of small children on the basis of observations made in Volkmann's clinic. The affection occurs not infrequently in the form of catarrhal suppurative arthritis in children from one to four years of age, is always non-articular, and attacks most commonly the shoulder, ankle, elbow, and hip joints. The course is very acute, and is accompanied by the symptoms of a phlegmon; but after freely opening the joint recovery usually takes place rapidly without disturbance of function. Satisfactory results are often obtained even in the cases where the pus has spontaneously ruptured externally, and in neglected cases. Not infrequently spontaneous luxations occur. Krause found the streptococcus pyogenes in the pus. Sometimes suppurative inflammations of joints are observed during early childhood in conjunction with injuries or the acute exanthemata; they are generally caused by the staphylococcus pyogenes aureus or albus, and have a pronounced pyæmic character.

Synovitis Crouposa.—Many authorities, including Bonnet, have recognised, in addition to the serous and suppurative synovitis, a croupous

synovitis which is analogous to the croupous inflammation of mucous membranes. In the croupous synovitis there are found in the cavity of the joint large amounts of coagulated fibrin; the affected joints are very painful, but only slightly swollen, and fluctuation is absent. The course of this more or less dry arthritis is unfavourable, inasmuch as the joint becomes obliterated in the majority of instances, and firm anchylosis results. As a matter of fact, there are inflammations of joints which run a very dry course; but Volkmann considers it questionable whether in these cases there is really a croupous inflammation of the joint.

Etiology of Acute Inflammations of Joints.—The causes of acute primary inflammations of joints are in the main traumatic, and are chiefly to be ascribed to infection of some injury by micro-organisms. Every suppurative arthritis is due to the presence of bacteria. In the case of a serous synovitis, however, taking cold cannot be left out of account as a primary or exciting cause. Primary acute inflammations of joints very often originate secondarily—i. e., they are either the result of disease of the adjoining tissues, such as the medulla, periosteum, etc., or they are the local expression of a general systemic infection—in other words, they are metastatic inflammations which generally develop simultaneously in several joints. In the latter category belong, for example, the inflammations of joints occurring in the course of pyæmia, typhoid fever, the acute exanthemata, and of pneumonia in consequence of infection by Fränkel's pneumococcus, also polyarticular rheumatism, arthritis urica (gout), gonorrhœal rheumatism, the inflammations of joints arising in the course of syphilis, chronic lead poisoning, etc. We must refer the reader to the text-books on internal medicine for the description of acute polyarticular rheumatism. It will suffice to say here that the entire course of this disease suggests an infection by micro-organisms with localisation in the joints and other serous cavities (the endocardium, for example). The inflammation of the joints is generally serous, but it may occasionally be suppurative in its nature. A. Monti found the diplococcus pneumoniæ of Fränkel and Weichselbaum in the pus of acute articular rheumatism. At all events there are many different kinds of micro-organisms concerned in the so-called acute polyarticular rheumatism.

The Secondary Inflammations of Joints which Occur in the Course of Acute Infectious Diseases (Pyæmia, Acute Exanthemata, etc.).—The inflammations of joints which occur in the course of acute infectious diseases (pyæmia, erysipelas, puerperal fever, measles, scarlatina, small-pox, typhoid fever, diphtheria, pneumonia, mumps, glanders, dysentery, etc.) are mostly of the suppurative variety, and the bacterial forms which are

characteristic of the primary disease are usually found in the exudate contained in the joint. In the case of pneumonia the suppurative arthritis following infection by Fränkel's pneumococcus may develop before or after the pneumonia itself. The pyæmic inflammations of joints run the course of an acute suppurative catarrh or of an acute pyæmic gangrenous arthritis, and the disease is almost always multiple. If the patient recovers from the pyæmia the inflammation of the joints will ordinarily subside with great rapidity, and not infrequently the joints will regain perfect motion where one would expect stiffness. Other cases run a very chronic course, like cold abscesses.

The inflammations of joints which occur in the course of the acute exanthemata (scarlatina, measles, small-pox, typhoid fever, diphtheria, dysentery, etc.) present the picture either of acute polyarticular rheumatism or of suppurative pyæmic arthritis. During convalescence from the acute infectious diseases, however, we meet with pronounced, serous, monarticular exudations into the joints which only cause a slight amount of pain ; this is particularly apt to happen in typhoid fever. O. Witzel has recently called attention to the frequent occurrence of inflammations of bones and joints during acute infectious diseases.*

Suppuration in Neuropathic Bone and Joint Disease.—Suppuration in neuropathic bone and joint disease is discussed in § 117. The analgesia which is the result of disease of the spinal cord (tabes, syringomyelia, etc.) and peripheral nerves is an important etiological factor in the production of this kind of suppurative arthritis, for the reason that the patients, in consequence of the absence of their sense of pain, neglect injuries which they receive, and this allows suppurative infection to take place.

Gonorrhœal Arthritis.—Great interest also attaches to the gonorrhœal inflammations of joints—gonorrhœal gout or rheumatism, as it is called. This form of arthritis is rendered thoroughly intelligible to us since we know that the specific catarrh of the urethra is excited by the gonococcus first described by Neisser. Petrone, Bornemann and others maintain that, as a result of the systemic infection which may occur from a gonorrhœa, not only the joints may become diseased, but also the tendons and tendon sheaths, the mucous bursæ, the nerves, the eyes, the endocardium and pericardium, etc. This gonorrhœal inflammation attacks by preference the knee joint, though the affection often occurs in a multiple form involving several joints, and as a rule is serous or sero-fibrinous, very rarely suppurative, in its nature. Quite often there is a very considerable exudation into the joint. In three hundred

* Bonn, Max Cohen & Son, 1890, p. 146.

and eight cases Nolan states that the knee was affected eighty-six times, the ankle fifty-two, the shoulder twenty-nine, the wrist twenty-six, the hip fifteen, the fingers and toes seventeen, etc. Out of one hundred and eighteen cases, only twenty-three were monarticular, and in fifteen cases many joints were involved. The course of gonorrhœal rheumatism in the majority of instances is favourable, and after the joint has been punctured once or twice the effusion disappears entirely, but recurrences of the affection are rather common. There are also cases which run a very chronic course, like tumor albus or arthritis deformans, and occasionally we encounter cases which are very malignant and rapidly pass on to suppuration. In these, as a rule, there is a mixed infection, and the cocci of suppuration will generally be found in the pus. But it is sometimes impossible, as Guyon, Janet and others have remarked, to demonstrate the presence of gonococci (see Special Surgery) even in a typical gonorrhœal rheumatism which does not suppurate. Bornemann maintains that gonorrhœal rheumatism should be looked upon as an ordinary infectious-wound disease due to an invasion of staphylococci and streptococci. The typical form of the disease generally makes its appearance during the first month which follows the gonorrhœa; according to Nolan, it developed sixty-four times within this period, eleven times in the course of the second month after the urethritis broke out, and twelve times after a still longer interval.

The Acute Inflammations of Joints which occur in the Course of Syphilis.—In the course of syphilis there are likewise observed monarticular and polyarticular inflammations of joints which are like a monarticular hydarthros of the knee, or, when polyarticular, like acute rheumatism. The chronic syphilitic inflammations of joints are discussed in § 114.

Gout (*Arthritis Urica*).—Gout is an expression of the uric-acid dyscrasia. The blood contains an excess of the salts of uric acid, which are deposited especially in the articular cartilage (Fig. 371), the capsule, the ligaments, and in the parts surrounding the joints. Erbstein, to whose painstaking study of gout we are greatly indebted, has produced the disease experimentally in cocks by tying off the ureters and destroying the secreting parenchymatous portion of the kidneys. This very painful inflammation occurs in the form of paroxysms, and most

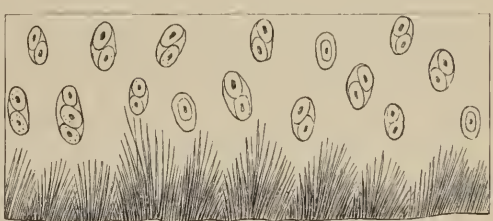


Fig. 371.—Deposition of needle-shaped crystals of urate of sodium in the articular cartilage in a case of gout. × 250.

commonly attacks the joints of the toes (*podagra*), less often those of the fingers or wrists (*chiragra*), for the reason that disturbances of circulation more readily take place in the terminal parts of the body. Arthritis urica is mainly a disease of the higher classes, and is more common in England than on the Continent, making its appearance at the earliest about the thirtieth to the thirty-fifth year of life. Gout begins with a serous effusion into the affected joint, which is very apt to be the one between the metatarsus and first phalanx of the great toe. Then follows the deposition in and around the joint of crystals consisting of urate of sodium and compounds of uric acid with calcium, magnesium, ammonia, and hippuric acid. The skin is very much reddened, and is exceedingly tender upon the slightest pressure. Usually a complete *restitutio ad integrum* ensues, but inasmuch as the attacks are frequently repeated, deforming inflammations of the joints may eventually develop, which consist in a fibrillation and abrasion of the cartilage, thickening of the synovial membrane, periarticular tissues, etc. There is also a formation of circumscribed nodules, gout nodes (tophi) as they are called, containing chalky deposits. Furthermore, patients with gout suffer from progressive degenerative changes in the internal organs, especially in the kidneys and walls of the vessels (atheroma of the vessels). The post-mortem examination of individuals who have had this disease reveals with remarkable frequency pulmonary emphysema and chronic interstitial nephritis; also calcification and degeneration of the valves of the heart, particularly those of the aorta, apoplexies of the brain in consequence of atheroma of the walls of the vessels, etc.

Acute inflammations of joints occurring in attacks and presenting a clinical picture which is like arthritis urica, are also sometimes observed in the course of *chronic lead poisoning*.

The Diagnosis of Acute Inflammation of a Joint.—The diagnosis of acute arthritis can in the majority of instances be made with ease from the description given above. In making the examination the diseased side should always be compared with the healthy one. Any exudate which may be contained in the joint adapts itself to the form of the latter. A test puncture with a hypodermic needle—which, of course, must be carried out with every antiseptic precaution—will give accurate information as to the nature of the exudate in the joint, whether it is serous or purulent. For the rest, I must refer the reader to what we have said as regards diagnosis in the chapter on Inflammation (see pages 251–252).

The Treatment of Acute Inflammation of a Joint.—The treatment of acute serous synovitis, acute hydarthros, consists, at the outset, in maintaining the part in a quiet (elevated) position, possibly with the aid of

splints, and in the application of ice. As soon as the inflammatory manifestations, especially the pain, have subsided, the serous exudate which may be present should be caused to disappear by compression with elastic bandages—the ordinary rubber bandage, for example—and by massage practised once or twice daily, and the patient then permitted to walk about. The treatment by rest should not be continued too long a time in acute hydarthros, for the reason that the affection may then easily take on a chronic character.

If the effusion is under great tension, if absorption is delayed, or if the hydrops has become chronic, the joint should be punctured *aseptically.* The area of skin over the joint is carefully scrubbed with soap, shaved, and washed with a five-per-cent. solution of carbolic acid or a one-tenth-per cent. solution of bichloride of mercury. The effusion in the joint is then compressed with the left hand, and the joint opened with a trocar which has been sterilised by boiling it for five to ten minutes in a one-per-cent. solution of soda (see page 69, Fig. 50), or by heating it red-hot, or with a large hollow needle of an aspirator similarly sterilised, or simply by puncture or incision with the knife. After the exudate has been evacuated the joint can be washed out with a three-per-cent. solution of carbolic or a one-tenth-per-cent. solution of bichloride. In pure serous effusions I usually avoid this washing out, but perform the operation if the effusion is sero-fibrinous and contains a slight amount of pus. After puncturing it the joint is immobilised by splints and an antiseptic dressing which exerts pressure. The aseptic puncture of a joint with the trocar, aspirator, or knife is entirely devoid of danger if the rules of asepsis are carefully observed and if pains are taken to prevent the entrance of air into the joint—in short, if the operation is performed with the utmost possible caution. Schede, in particular, has obtained satisfactory results by antiseptic puncture and washing out the joints in hydrops, hæmarthros, etc.

Treatment of Acute Suppurative Arthritis.—If there is pronounced suppuration in a joint, aseptic puncture followed by irrigation of the joint with a three-per-cent. carbolic or one-tenth-per-cent. bichloride solution may be practised in those cases in which the suppuration is still in its inception; but if the suppuration is well marked and there is high fever, the joint must be immediately opened by a free incision and drained (§ 31), and, if necessary, resection of the joint (§ 40) must be performed. If the test puncture (with the hypodermic needle) reveals acute suppuration, the expectant treatment by elevation, ice, and immobilising dressings, which used to be employed, should be discarded, and operative treatment by incision and drainage or resection should be straightway adopted in its place. *Ubi pus ibi evacua!* After the

operation the joint is placed in a suitable position and carefully immobilised by splints and antiseptic dressings. When the arthritis is suppurative a careful examination should always be made to determine whether periarticular collections of pus are present. In cases where the suppuration is severe, permanent antiseptic irrigation should be used (page 178). In the worst forms of suppurative arthritis with putrefactive changes it is often necessary to perform an amputation in order to save the patient's life. If after suppuration of a joint recovery takes place, with motion in the latter, we improve the motility as much as possible, after the inflammation has completely subsided, by passive motion, massage, and electricity. If recovery takes place with anchylosis, the joint must be made to assume a position which will be as useful as possible for the patient. The ankle and the elbow, for example, should be kept in a right-angled position, but the other joints must be extended.

The treatment of the secondary, metastatic inflammations of joints is precisely the same as for those which are primary. If many joints are attacked by suppuration, and there is a severe or hopeless constitutional disease, one would probably relinquish all idea of adopting energetic operative measures, and simply provide an escape for the pus by incision and drainage, and alleviate any pain which the patient may suffer.

Treatment of Acute Polyarticular Rheumatism.—Acute polyarticular rheumatism is treated by immobilisation of the joints with splints of wood, pasteboard (see page 223), or water-glass; by placing the limb in an elevated position, and by administering internally diaphoretics and diuretics, particularly salicylic acid or salicylate of sodium (3·0 to 6·0 grammes *pro die*). I ordinarily give to adults four to six grammes of salicylate of sodium in wafers or a mucilaginous mixture (with aq. dest. and mucilag. gummi mimos., āā 50·0 grammes) about every two to three hours. If 0·50 to 1·0 gramme of salicylic acid are given in wafers, or the above-described mixture, one should not neglect to make the patient drink a glass of water after each dose, as otherwise the stomach may easily become disordered. I must refer the reader to the text-books on internal medicine for the rest of the treatment of acute polyarticular rheumatism, including any cardiac complications which may arise.

Treatment of Gout.—The *local treatment of gout* consists in alleviating the pain by placing the part in a proper (elevated) position and in enclosing the inflamed joint in cotton, so as to exert pressure. The joint in question is painted over with fat or vaseline and enveloped with dry cotton, or a hydropathic dressing is applied around it. Lithium,

salicylate of sodium, etc., are given internally. Diaphoretic remedies are supposed to shorten the attacks. The patient is put upon a light diet, and Moselle wine with seltzer, or some such beverage, is given him to drink. The morbid diathesis is treated by a moderation in the patient's mode of living, especially as regards alcohol, by a meat diet, which must not be too excessive, and by the use of Carlsbad, Kissingen, Marienbad, Wiesbaden, Levico, Vichy, and other saline-spring waters; the hot baths of Gastein, Teplitz, Wiesbaden, etc., are also worthy of recommendation.

Treatment of Gonorrhœal Rheumatism.—The milder cases of *gonorrhœal inflammations of joints* are treated by rest in bed, by ice, by immobilising dressings, and by a simple diet. Internally we occasionally give four to six grammes of salicylate of sodium *pro die.* In the case of large effusions puncture and antiseptic irrigation of the joint, as described above, should not be too long delayed. In the rare instances of suppuration of the joint the rules given on page 665 should be followed. For gonorrhœal rheumatism Vogt recommends the injection of a bichloride-of-mercury solution into the joint (0·1 gramme bichloride, 1·0 gramme sod. chlor., and aq. destil. 50·0 cubic centimetres; three to five hypodermic syringes to be injected into the joint each time at intervals of three days). König praises injections of a five-per-cent. carbolic-acid solution. During the acute inflammatory stage of the arthritis the treatment of the gonorrhœa which is present should be deferred, but later, under all circumstances, it must be cured as soon as possible (see Special Surgery). After the inflammation of the joint has subsided it will often be advantageous to wear an elastic bandage, and a splint apparatus may possibly be necessary, particularly in the case of the knee, if the latter has been inflamed for some time. I do not think that massage should be used after the subsidence of a gonorrhœal arthritis, for the reason that recurrences of the affection may thus be lighted up, the micro-organisms being again introduced into the circulation and carried off to other portions of the body. I have seen very satisfactory and permanent cures brought about in protracted and malignant cases by a residence in southern climates—Riviera, Sicily, Egypt, Tunis.

The symptomatology and treatment of the acute inflammations of individual joints is described in the Text-Book on Special Surgery.

§ 114. **The Chronic Inflammations of Joints.**—The chronic inflammations of joints are divided, according to differences in pathology, into two main groups, namely, the *dry* (arthritis sicca) and the *exudative* inflammations of joints (arthritis exudativa, with or without a formation of new tissue or of granulations). The subject of chronic arthritis

is of very great practical importance, and, among others, Billroth, Bonnet, Volkmann, Ollier, C. Hueter and König have done much to advance our knowledge of it.

I. **Arthritis, or Synovitis Chronica Serosa** (*Hydarthros, Chronic Hydrops of a Joint, Chronic Dropsy of a Joint*).—Hydarthros, or chronic articular hydrops, either begins very gradually as such, or it follows an acute serous synovitis.

The pathological changes which occur in a synovitis chronica serosa (hydarthros) are essentially as follows: The fluid which collects in the joint is either thin and watery, or it is thick, gelatinous, or colloid. The exudate is sometimes remarkably rich in endothelium (Volkmann's endothelial catarrh). The secondary changes in the cartilage and capsule of the joint are usually slight; but after the process has lasted a long time the synovial membrane becomes thickened, the villi are increased in size and numbers, the joint cartilage becomes thickened and fibrillated, and the synovial membrane grows over the free surfaces of the cartilage (Hueter's synovitis hyperplastica lævis or pannosa). The synovial membrane occasionally projects through the stretched external fibres of the capsule in the form of a synovial hernia. After the hydarthros has existed a long time the ligaments and capsules of the joint become stretched, sometimes to such a degree that the joint loses its normal firmness and becomes flail-like, and displacements, subluxations, or complete luxations of the articular ends of the bones follow. If a rupture of the capsule of the joint takes place spontaneously, or as a result of a traumatism, a periarticular effusion will make its appearance. The neighbouring mucous bursæ which communicate with the joint are often similarly diseased.

The *causes* of hydarthros are traumatisms (contusions and sprains), infection, such as syphilis or gonorrhœa, taking cold, and the presence of loose bodies in the joint.

The *symptoms* are in the main the same as those of an acute serous arthritis, with the single difference that inflammatory manifestations are usually absent. Hydarthros, or chronic serous synovitis, most commonly occurs in the knee, and in this situation the effusion into the joint can best be demonstrated by placing the leg in the extended position. Very often, if the affected joint is moved, a creaking and rubbing can be felt and heard, and is mainly caused by a thickening of the synovial membrane, by hypertrophy of the villi, together with an increase in their number, and by fibrillation of the cartilage, or by the formation of loose joint bodies. The tendency to the formation of free joint bodies (see § 115) in hydarthros occasionally exists in a marked degree. The course of chronic serous synovitis or hydarthros

is generally favourable if the disease receives proper treatment, and only in rare instances do we meet with the above-mentioned deforming changes in the synovial membrane, the articular cartilages, or in the entire articular apparatus.

The best treatment for *chronic serous synovitis* consists in the use of massage (see page 505) and of compression of the effusion by means of rubber or elastic bandages. It is of the utmost importance that the patient should not protect his joint—should not keep it quiet—but rather should use it industriously. If this does not bring about a cure and cause the effusion to disappear, the latter should be removed in the manner described above, by aseptic puncture, with or without a subsequent washing out of the joint with a three-per-cent. solution of carbolic acid or with a one-tenth-per-cent. solution of bichloride of mercury. After the puncture the joint must of course be immobilised in a suitable (elevated) position during the next few days by an antiseptic dressing applied so as to exert pressure. If the reaction following the irrigation is too severe, it should be combated with ice. As a general thing, simple evacuation of the effusion by puncture, without antiseptic irrigation, will suffice in the majority of cases of hydarthros. A few days after removing the effusion the joint should be massaged and vigorously moved, and from time to time enveloped in an elastic bandage. Any recurrences which may take place can be speedily cured by massage, elastic compression, and movement of the joint. The treatment at one time much in vogue, by irritation of the skin (tinct. of iodine) and by the administration of internal remedies (tartar. stibiat.), has very properly been abandoned, and keeping the joint quiet is actually injurious. I never make use of the injection of tincture of iodine into the joint—a procedure by no means devoid of danger.

II. **Chronic Articular Rheumatism** (*Rheumatismus Chronicus Articulorum, Polyarthritis Rheumatica Chronica*).—By chronic articular rheumatism we understand an inflammation of the synovial membrane running an exceedingly slow course, which occurs almost exclusively in adults, generally after the thirtieth to the fortieth year, and always attacks several joints. There is generally a gradually increasing disturbance in the function of the joints, which ordinarily in the end leads to complete stiffness or anchylosis of the joint.

The *anatomical changes* which occur in chronic articular rheumatism consist essentially in a chronic inflammatory formation of new connective tissue in the synovial membrane and surrounding parts which have a tendency to shrink and become hard and dense, in a fibrillation of the cartilage, and in a substitution for the latter of vascu-

lar connective tissue. The connective-tissue metaplasia of the cartilage is brought about mainly by growth on the part of the synovial membrane, though it is very largely promoted by the increased formation of medullary spaces in the deeper layers of cartilage, and by inflammatory changes with a formation of new vessels in the subchondral medulla. As the new formation of connective tissue increases, the cavity of the joint grows steadily smaller. The stiffness of the joint, the anchylosis, is at the outset due to connective-tissue adhesions which may eventually ossify, the process spreading from the spongiosa until the entire joint may become filled with bone. Chronic articular rheumatism never leads to suppuration, and never to true caries, the pathological changes presenting more of a similarity to arthritis deformans, except that in the latter disease there is more an increased growth of cartilage, while in the former the cartilage is replaced by vascular connective tissue. But deformities of the joints, subluxations and luxations develop in chronic articular rheumatism as they do in arthritis deformans.

Chronic articular rheumatism either follows an acute rheumatism, or it begins insidiously as a chronic disease which lasts many years, and is very frequently—in fact, as a rule—incurable. Gradually many different joints become affected, and, in rare instances, all the joints of the body. The disease is most common in the lower walks of life, and hence the name arthritis pauperum. The causes which are given for it are particularly taking cold, getting wet through, damp dwellings, etc. It is observed almost exclusively in adults; and only in exceptional instances are severe cases with deformities of the joints, resembling arthritis deformans, met with during childhood (Wagner). As in acute rheumatism, it is still uncertain as to how much of a part is played by micro-organisms in the production of the chronic polyarticular rheumatism.

The subjective symptoms consist in sharp, severe pains felt now in this and now in that joint. The movements of the joints, particularly in the morning, after the night's rest, are limited and cause pain; but during the day, after the patient has used his limbs somewhat, the mobility of the joints improves. In other instances the joints are so painful that no movements at all can be performed. The joints are usually somewhat swollen; and in many cases—i. e., in the so-called fungous form of articular rheumatism—the growth of connective tissue is so considerable that the joints present the appearance of tumor albus. If the joints are moved, a creaking or crackling friction sound, due to the newly formed connective tissue and to the fibrillation of the cartilage, can very frequently be made out. As a rule, subacute

exacerbations of the subjective and objective symptoms take place at irregular intervals, the joints become steadily stiffer, and the muscles atrophy more and more, so that these pitiable individuals grow constantly more helpless, and death often occurs from general marasmus or some intercurrent disease. In other cases the disease gets well with partial or total anchylosis of the affected joints. I saw a divinity student who had complete anchylosis of both hips, both knees, the right elbow, and the left wrist; and Percy found anchylosis of all the joints of the body in a French officer who died in his fiftieth year. The skeleton of this officer, who had suffered from chronic articular rheumatism contracted in his campaigns, has been preserved in the École de Médecine, and forms, to all appearances, a single piece of bone.

The diagnosis of chronic polyarticular rheumatism can, in all probability, be readily made from what has been said above; but the milder cases are often difficult to differentiate from gout and arthritis deformans. We have also made the prognosis sufficiently clear.

The treatment of chronic polyarticular rheumatism generally demands a great deal of patience, and even then, I am sorry to say, is often entirely unsuccessful. In cases which are not of long standing, massage and methodical exercise of the joints should be tried in combination with hydrotherapy (baths, steaming, douches, etc.). The joint should not be kept quiet in the early stages of a chronic rheumatism. If massage and movement of the joint are too painful, they must be carried out occasionally under chloroform anæsthesia. I have seen very satisfactory and permanent cures obtained by this treatment in cases which had not existed too long a time. Furthermore, the use of hot springs, such as Gastein, Teplitz, Wiesbaden, Wildbad, and Ragatz-Pfäffers, and a residence in warm climates, are very valuable. Volkmann recommends the internal administration of cod-liver oil and iron, and iodide of potash or vinum semin. colchici. The use from time to time of salicylic acid or salicylate of sodium is exceedingly serviceable. But often on account of the severe pain massage cannot be carried out, or the joints may already have undergone too extensive changes. In such cases, which are generally of long standing, we are often compelled to confine ourselves to orthopædic treatment, placing the diseased joints in a good position, under chloroform anæsthesia, and immobilising them by plaster-of-Paris splints. As a result of the rest given the joints by the plaster of Paris, the pain ordinarily becomes less, but at the same time the occurrence of anchylosis is favoured. After having kept the diseased joints quiet by splints for a long time,

it has been my experience that all hopes of the possibility of obtaining a cure with a movable joint must generally be given up, and a recovery with anchylosis be striven for. Sonnenburg has recently obtained very surprising success in chronic articular rheumatism by laying the joint widely open (arthrotomy) and then washing it out antiseptically and packing the cavity with iodoform gauze. Schüller recommends injections of a sterilised two-per-cent. boro-salicylic solution or a three- to five-per-cent. iodoform-glycerin solution; but in the severe chronic cases he also advises operative treatment, such as arthrectomy (see page 129). I have not seen any success from intra-articular injections in chronic rheumatism, but I believe, with Sonnenburg and Schüller, that chronic articular rheumatism in its later stages, especially if there is great pain, should receive operative treatment more frequently and earlier than it ordinarily does. Sonnenburg's method of freely opening the joint, washing it out antiseptically and packing it with iodoform gauze will generally suffice, though if the disease is severe arthrectomy may be indicated.

III. **Chronic Suppuration of Joints.**—Every suppuration of a joint is the result of infection by micro-organisms. The infection takes place in conjunction with a traumatism, for example, or by way of the circulation, or in consequence of the extension to the joint of a suppurative inflammation in the surrounding parts (medulla, periosteum, soft parts). In chronic suppuration of a joint the synovial membrane is usually the seat of an inflammatory infiltration and is covered with fibro-purulent masses, the cartilage is cloudy and fibrillated, and losses of substance develop in it (cartilage ulcers); occasionally large portions of the cartilage necrose and separate from the underlying parts, or the cartilage is completely destroyed. The suppuration very often spreads to the medulla, the periosteum, and the periarticular tissues. The joint becomes more or less altered according to the severity and duration of the suppuration, and in pronounced cases which have existed for a long time fibrous or bony anchylosis usually develops when recovery takes place, as we remarked before in discussing the subject of acute suppurative arthritis.

We shall first take up that form of chronic suppuration of joints which is due to tuberculosis.

IV. **The Chronic Fungous and Suppurative (Tubercular) Inflammations of Joints—Tuberculosis of Joints—Tumor Albus—Tubercular Caries of Joints—Fungus of Joints.**—All these terms indicate one and the same disease, viz., tuberculosis of joints or tubercular arthritis.

Tubercular arthritis is generally a secondary inflammation—i. e., it originates most commonly in conjunction with a tubercular focus in

the medulla (in the epiphyses of the long bones, for example, or in the periosteum); less frequently the tuberculosis is primary in the joint. Primary tuberculosis of a joint may begin in any part of it, particularly in the bone and synovial membrane; but, as far as I know, no case of primary tuberculosis has hitherto been observed which originated in the ground substance of the cartilage. Müller's statistics, obtained from König's clinic, show that in two hundred and thirty-two cases of tubercular arthritis one hundred and fifty-eight started in the bones, forty-six in the synovial membrane, and in twenty-eight cases the point of origin was uncertain. We remarked on page 610 that the anatomical structure of the medulla is especially favourable to a deposition from the blood of the tubercle bacilli, and we likewise emphasised the fact that tubercular arthritis develops very often after the reception of some traumatism. The general subject of tuberculosis and of tuberculosis of bone is described in § 83 and § 105, and therefore we shall confine ourselves here to the presentation of the tuberculosis which is peculiar to joints.

The Pathological Changes which Occur in Tubercular Arthritis.—The pathological changes which occur when a joint is infected by tubercle bacilli, no matter whether the infection is primary in the joint or secondary to similar disease in the medulla, periosteum, or periarticular soft parts, are as follows: The bacilli enter by one or more points of infection, and are, so to speak, planted in different parts of the joint, where they give rise to the development of tubercles which have the structure that we described on a previous page (407). The synovial membrane undergoes inflammatory changes, and is filled with characteristic greyish-white nodules, and as the tuberculosis advances it is possible to distinguish three different forms of the disease, which, to be sure, merge into one another: (1) The *pure miliary form*, without the formation of a spongy, so-called fungous tissue, (2) the *fungous form*, and (3) the *fibrous*, with the formation of lardaceous thickenings. The fungous form of tubercular arthritis is the most common, and in it the synovial membrane becomes changed into a spongy, red granulation tissue filled with tubercles, while during the early stages the joint contains a serous or sero-fibrinous exudate (hydrops tuberculosus), and later on pus in which there are generally small particles of cheesy matter (cold, tubercular, suppurative arthritis). The tubercular granulation tissue in course of time grows into all parts of the joint, pushes its way over the cartilage and ligaments, and penetrates into the bone and medulla, etc.; in short, wherever the tubercular granulation tissue develops the original tissue is destroyed. In the case of tuberculosis of bone the portion of the latter which is affected by the disease either

necroses *in toto* (Fig. 372), or several isolated sequestra are formed (Fig. 373). In the caput femoris, for example, very characteristic cuneiform sequestra are frequently observed (Fig. 372) which are similar to the

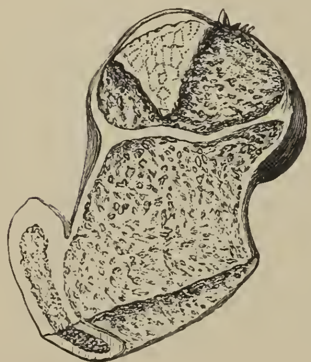


Fig. 372.—Large infarct-shaped subchondral tubercular focus in the head of the femur, which is in an advanced stage of demarcation; the articular cartilage is lifted up like a pustule. Early resection, five-year-old girl. Recovery.

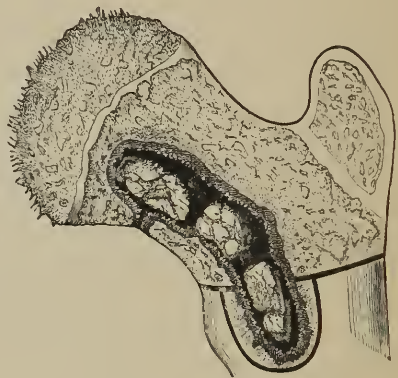


Fig. 373.—Tuberculosis of the neck of the femur with three sequestra. Secondary tuberculosis of the hip-joint; the cartilage of the head of the femur is destroyed. Resection of the hip. Eight-year-old boy (Volkmann).

so-called infarcts—i. e., the necrosis of tissue resulting from occlusion of the terminal, afferent arterial vessel. These infarcts have the form of a wedge which corresponds to the distribution of the terminal branches of the affected vessels. The cuneiform sequestra which are met with in tuberculosis of bone are probably due in the same way to the plugging of the terminal artery at the apex of the wedge with tubercle bacilli. If the tuberculosis begins in the bone the articular cartilage either becomes perforated like a sieve by the tubercular inflammation, or it is raised from the underlying parts more or less *in toto*, as in Fig. 372. In the later stages large portions of articular cartilage may be separated *in toto* from the

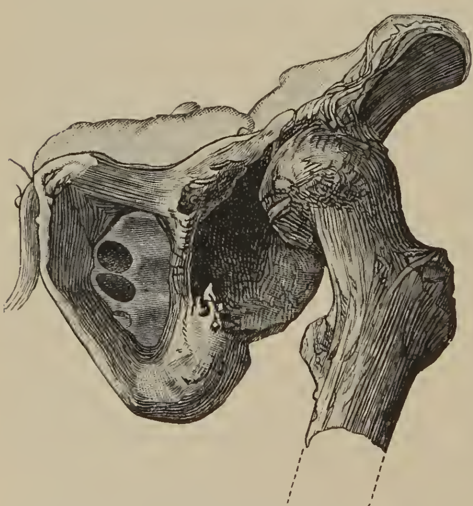


Fig. 374.—So-called wandering of the acetabulum in coxitis ("intraacetabuläre Luxation").

bone, or the cartilage may be completely destroyed, as in Fig. 373. It is very fortunate for the patient if the tubercular process, for example, in the epiphysis of a long, hollow bone does not attack the joint but breaks through externally to it. This extra-articular breaking through of bone tuberculosis in the neighbourhood of a joint is a rather common occurrence. After the tubercular inflammation of the joint has broken through the joint capsule there follows a development of periarticular tubercular inflammation and suppuration with extensive collections of pus—the so-called congestion, cold, or gravitation abscesses which we have spoken of in a previous chapter. Not infrequently the extra-articular tubercular abscesses originate by infection through the lymph channels without a rupture of the capsule having taken place, and without the existence of any visible communication between the intra- and extra-articular suppurative processes. If the lymph glands connected with the joint become infected by tuberculosis, the danger of the tubercle bacilli being carried further—in other words, the danger of a general tuberculosis—becomes more imminent. Very often the tubercular inflammation works its way outwards through the skin spontaneously, and gives rise to fistulæ which frequently pass a long distance through soft parts and bone.

Fig. 375.—Tubercular kyphosis of the vertebral column (Sayre).

The destruction of tissue which takes place in tubercular arthritis, and is the result of the progressive change of bone, cartilage, and soft parts into tubercular granulation tissue, which breaks down and undergoes cheesy degeneration and suppuration, is sometimes very considerable. The entire head and neck of the femur may thus be destroyed by caries and necrosis, and not infrequently extensive ulcerative processes lead to perforation of the acetabulum. Very often the latter becomes enlarged in an upward direction, and the head of the femur, following the change in the shape of the acetabulum, is caused to assume a higher position—a phenomenon which is called "wandering of the acetabulum" (Fig. 374). In the spinal column entire vertebræ may be destroyed, giving rise to corresponding deformities, especially kyphosis or Pott's hump

(Fig. 375). Furthermore, in tuberculosis of the vertebræ, the cold, congestion abscesses which gradually burrow downwards may attain a considerable size; they usually follow the course of the ilio-psoas muscle, and may eventually come to the surface in the thigh beneath Poupart's ligament.

If left to itself a tubercular focus may heal up at any stage of its existence. Recovery often takes place only after the joint has become completely obliterated or anchylosed, but not infrequently the cure is only apparent and temporary. If the joint has not been immobilised in a proper position while the tubercular disease was in progress, contractures are very liable to take place; and if these affect the knee or hip, the use of the leg may be seriously interfered with or rendered impossible (see Fig. 376).

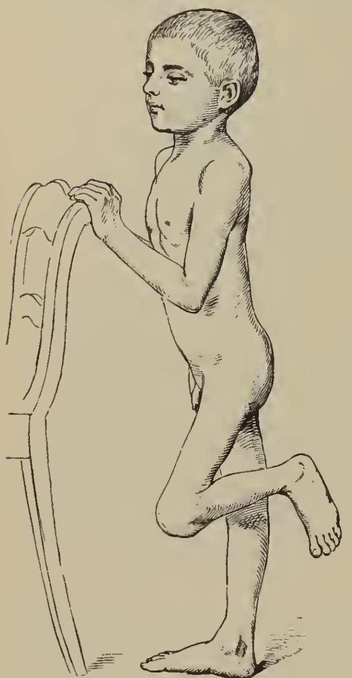


Fig. 376.—Tubercular contracture and anchylosis of the knee of a six-year-old boy. Cuneiform resection followed by healing in the extended position.

The Development of Tubercular Arthritis after the Injection of Tubercle Bacilli into the Joints of Animals.—If pure cultures of tubercle bacilli are injected into the joints of guinea-pigs there will be observed, after the lapse of four to six days, an increasing inflammatory swelling and exudation into the joints under consideration, and towards the end of the third week the presence of tubercle bacilli can be plainly made out, and pus will be found in the joints. Pawlowsky states that the tubercle bacilli are located mainly in the lymph passages and connective-tissue cells. If intravenous injections of attenuated (weakened) cultures of tubercle bacilli are practised in rabbits, the typical picture of tubercular disease of joints will sometimes be obtained only after four to five to six months, while the other organs will remain healthy (Courmont, L. Dor).

Tubercular arthritis runs an exceedingly chronic course, as a rule, and often lasts many years. The disease most commonly attacks children, though adults of all ages are not exempt from it. The joints most frequently affected are the knee, the hip, the astragalo-tibial joint, and the joints of the tarsus. Tubercular arthritis generally begins very gradually, but in rare instances is more or less acute in its onset. The first symptoms of tuberculosis involving the knee joint

of a child, for example, are a proneness to fatigue and a slight limp or dragging of the leg in walking, and after having been on its feet for some time; or, if pressure be made, the child will complain of pain in the joint. The first objective symptom is generally a moderate amount of swelling, which causes the furrows beside the patella to become less plainly marked than upon a healthy knee. The initial symptoms manifested by joints which are more deeply placed are not so apparent as they are in the knee. As the disease progresses the swelling of the knee gradually increases, and the normal contour of the joint disappears to a greater and greater extent. The swelling feels rather hard. or it is more soft and spongy, and is caused either by a thickening of the synovial membrane and periarticular connective tissue, or, as in primary osseous tuberculosis, by enlargement of the articular ends of the bones. The skin is ordinarily more or less tense, and presents a white, waxy appearance, which gave rise to the term tumor albus, formerly used to designate this condition. As the swelling becomes greater the pain in the joint increases, and is made worse by pressure and attempts at motion. The pain, however, is not always felt in the diseased joint, as in tubercular inflammation of the hip (coxitis), for example, the children very often complain of pain in the knee, which might lead an inexperienced person to search for the disease in the wrong place. This pain in the knee accompanying tubercular coxitis is particularly apt to be present when there is tubercular disease of the medulla, the pain shooting through the latter down to the lower epiphysis; the phenomenon used to be looked upon as a reflex manifestation. Standing and walking eventually become impossible, and the tubercular inflammation causes the joint to grow more and more immovable. The knee and elbow are usually flexed to a greater or less extent, and the hip assumes a position in flexion, abduction, and outward rotation. At the outset the abnormal position of the joints can be corrected under chloroform anæsthesia, but later this cannot be accomplished without operative interference. The distorted positions of the joints—the contractures—may sometimes, as a result of improper treatment, become very excessive, as illustrated in Fig. 376; but contractures like this can always be easily prevented by the use of retentive dressings applied at the right time.

Attempts have been made to explain this abnormal position assumed by inflamed joints by (1) the mechanical theory advanced by Bonnet, and (2) by the reflex theory. Bonnet demonstrated by intra-articular injection of a liquid that the joint thus treated assumes a position in which its capacity is greatest—i. e., increasing its contents forces a joint like the knee to become flexed. According to the second

theory, a reflex muscular contracture is produced by the irritation of the synovial membrane. Both theories are right as far as they go, but by themselves are not sufficient to answer the question—a fact which Volkmann has correctly insisted upon. It must be borne in mind that the patient instinctively places his joint in a position which diminishes the pressure on the joint surfaces and causes him the least pain. Moreover, the mechanical conditions connected with the use of the diseased extremity, the longitudinal growth of the bone, and subsequently the changes which take place in the shape of the articular ends of the bones, have an influence upon contractures (see pages 549 and 554).

The further course of tubercular arthritis—sometimes called the *second stage* of the affection—is characterised by an increase of all the pre-existing symptoms, especially the swelling, fixation, and pain, and, in addition, there are very often manifestations of suppuration in the joint; in other words, a high fever develops, the joint becomes very painful at some particular point, and, finally, fluctuation can be detected. Suppuration in the joint is either accompanied by inflammatory manifestations of variable intensity, or it runs its course as a cold abscess. The amount of pus which is present is by no means constant, being in some instances very considerable, while in others the formation of pus is slight, although the destruction of the articular ends of the bones may be very marked. Permanent deformities develop in consequence of these changes in the bones, as well as the so-called pathological or spontaneous dislocations. The anatomical changes which follow suppuration in a joint, the development of periarticular abscesses from rupture of the pus in the joint through the capsule or from infection through the lymphatics, the occurrence of extensive gravitation abscesses, etc., have all been described above.

The patients' *general condition* is ordinarily very much altered for the worse; they are emaciated, anæmic, without appetite, and not infrequently have diarrhœa and more or less fever.

Tubercular arthritis terminates either in recovery, or in death from systemic tubercular infection, from tuberculosis of the internal organs, especially the lungs and intestine, from increasing marasmus, from amyloid degeneration, or from some intercurrent disease. Tuberculosis is the most common cause of death. Of one hundred and thirty-five cases of tubercular arthritis which ended fatally, Albrecht states that sixty-four were due to tuberculosis, twenty-three to marasmus, and fourteen to amyloid changes; while in thirty-four the cause of death was unknown. Billroth maintains that the danger of pulmonary tuberculosis is greater after tubercular arthritis occurring in the upper extremity than when the disease affects the lower.

As a general thing it requires a very long time, often years, for recovery to take place spontaneously from tubercular arthritis. In such cases there is a gradual abatement of the local manifestations, the general health improves, and any fistulæ which may be present close up. When spontaneous recovery takes place from a pronounced tubercular arthritis with fistulæ, the joint which has been affected always becomes stiff. If no appreciable suppuration has occurred, recovery not infrequently follows without operative interference and with perfect motion in the joint in question. It is scarcely possible to say with certainty when joints which have been affected by tuberculosis have gotten entirely well, for relapses have taken place even after anchylosis has existed for years. With the modern methods of performing surgical operations we are able to give a more favourable prognosis, both as regards the preservation of the joint and the life of the patient. Nevertheless, the prognosis of tubercular arthritis, as Billroth has remarked, is in so far unfavourable as such individuals do not reach an advanced age. There are, for example, only comparatively few people with anchylosis due to tuberculosis who live to be more than forty or fifty years old; and Billroth says that only the minority of children who have been operated upon for tubercular caries of a joint, and cured, attain adolescence.

Treatment of Tubercular Arthritis.—The therapy of tubercular arthritis comprises local treatment of the diseased joint, and measures designed to improve the general health and render the system capable of successfully carrying on the struggle for existence with the tubercle bacilli. This constitutional treatment is described on pages 420 and 424 (Constitutional Treatment of Tuberculosis and Scrofula).

Inasmuch as tubercular arthritis gets well, though very slowly, under proper local and constitutional treatment without operative interference, it would be entirely wrong to immediately subject every case of tuberculosis of joints to operation. Therefore, at the beginning of the tubercular arthritis, the local treatment should be directed towards securing absolute rest for the joint by means of hardening dressings (see § 54, plaster of Paris, water-glass), or some of the various kinds of splints (see § 53), or by permanent extension (see § 55), the latter being particularly applicable for the hip. Sayre and Taylor have invented ingenious extension appliances for the lower extremity which enable the patient to walk about. It is also very advantageous in the case of coxitis to place a raised sole under the foot of the sound side, and, by using crutches to walk with, thus keep in suspension the diseased leg, which should be maintained in a fixed position by Thomas's splint (see Spec. Chir., Bd. II, p. 623). Hydropathic applications or ice may also be

employed for acute or subacute exacerbations which are accompanied by pain. If contractures of the joints are already present when the case comes under observation, they must be gradually overcome by retentive (see page 218) or extension dressings, often with the aid of chloroform anæsthesia. Great care must be taken in correcting the position of a joint which has become distorted ; it will often be impossible to remedy matters all at once, and the desired result will have to be accomplished gradually in several sittings. Each time that the contracture is improved the joint should be immediately fixed in its new position by a plaster-of-Paris dressing. Massage should never be practised at the beginning of a tubercular arthritis, as I have repeatedly seen severe constitutional tubercular infection caused by quacks who have prescribed it.

Injections of sterilised ten-per-cent. iodoform oil or ten-per-cent. iodoform glycerin (Bruns) are exceedingly valuable at the commencement of the tubercular inflammation of a joint, and later on when fistulæ have developed. The manner of preparing and sterilising the iodoform-oil emulsion is described on page 626. According to the age of the patient and the size of the affected joint, about every two to four weeks from two to five to ten grammes of the above mentioned mixture are injected into the joint and scattered through the latter as far as possible by careful motion and gentle massage. I have seen very remarkable success obtained by these iodoform injections. Injections of carbolic acid, of a strong solution of chloride of zinc (Lannelongue), and of arsenic (acid. arsen. 1 to 1,000, and of this one to two hypodermic syringefuls each day, combined with the internal administration of 0·004 to 0·012 gramme arsenic *pro die*), of iodoform ether, balsam of Peru, cinnamic acid (see page 420), etc., have also been recommended.

The treatment of tubercular arthritis by Koch's tuberculin has been discussed on page 421. I have not seen any satisfactory results from its use. Bier's treatment by constriction for the purpose of causing stasis is described on page 421, and the other methods for treating tuberculosis in § 83.

It is not always an easy matter to decide whether operative measures are necessary, for the simple reason that one cannot always be sure of the exact nature of the pathological changes which are present—a matter which König is right in calling attention to. In former times, when the antiseptic method of treating wounds was first introduced, surgeons went too far and performed resections of joints too often, particularly in the case of children who suffered from tubercular arthritis. But at present conservative treatment is employed as much as possible, and many joints, which would formerly have been sacrificed by per-

forming total resection, are now saved by iodoform injections, by excision of the synovial membrane, or by scraping away the diseased tissue.

Richet, Kocher and Vincent have recommended ignipuncture or punctiform ustion made with the fistula tip of the Paquelin cautery or with the galvano-cautery. I believe that this procedure is suitable for tuberculosis of the synovial membrane which has not become too extensive; but after the fungous granulations have passed into the stage of suppuration energetic operative measures are required. The joint, after being artificially made bloodless, is opened and the diseased parts then removed with great care by means of scissors, forceps, and the sharp spoon; but typical resection of the articular ends of the bones should be performed only in extreme cases (see § 40). If the tuberculosis is purely of the synovial variety, and the bones are healthy, we should, of course, preserve the latter and content ourselves with excision of the diseased membrane (arthrectomy). Early as well as late resection of all children's joints, with the exception of the hip, should be confined to as small a number of cases as possible; energetic scraping away of the diseased bone with the sharp spoon, but sparing the epiphysis, or extirpation of the diseased synovial membrane, but leaving the bone untouched or removing some of the cartilage, will almost always be found sufficient. By performing early arthrectomy with preservation of the articular ends of the bones in their entirety, or as much of them as possible, a permanent cure can often be obtained, and that, too, with a movable joint, a fact which is attested by Angerer's numerous cases. Amputation is only permissible in cases where the saving of life comes into the question, where the destructive processes have become very extensive, or where the patient cannot survive the long period of time required for a resection to heal. Other complications are treated according to the general principles which apply to them. Cold abscesses can with impunity be freely opened, thoroughly scraped out and drained. It is very important to recognise a tubercular focus in the neighbourhood of a joint before it breaks through into the latter, and to remove it with the sharp spoon. After every operation for tubercular arthritis the wound should be disinfected as carefully as possible to prevent infection with bacilli from the wound. Iodoform and iodoform gauze seem to be the most suitable dressing materials, especially for packing the joint. When a tubercular inflammation of a joint has got well, some suitable splint apparatus, such as one of those devised by Sayre, Taylor, or Thomas, should be worn, especially on the lower extremity, to support the limb, which will still be weak. If any abnormal conditions, such as contractures, follow a tubercular arthritis, they may have to be treated by

tenotomy of the shortened muscles—or, rather, tendons—by resection, arthrotomy, or by a wedge-shaped osteotomy, below the trochanter, for example, when the contracture involves the hip, unless they can be stretched under anæsthesia or gradually overcome by extension or retentive appliances (see page 216).

The treatment of tuberculosis of the individual joints will be described in the Special Surgery.

V. **The Syphilitic Diseases of Joints** (see also § 84, Syphilis, and page 628, Syphilis of Bone).—The syphilitic diseases of joints have lately been frequently and accurately described by such men as Schüller, Gies, Falkson, etc., and their occurrence can be readily understood if we bear in mind that syphilis is a specific infectious disease. The joints become affected in the course of syphilis, sometimes primarily and sometimes secondarily, after syphilitic disease in the surrounding parts, particularly the periosteum and medulla. The syphilitic inflammations of joints may be met with during the early stages of the disease at the time of the febrile eruption, or during the later periods. The early forms are, in the main, serous synovites, which occasionally make their appearance in a manner analogous to acute polyarticular rheumatism. The inflammations of joints which occur in the later stages of syphilis have, as a rule, a pronounced chronic character, and are generally connected with the formation of gummatous deposits in the periosteum, the medulla, and the synovial membrane. After the gummatous nodules have come to the surface and ruptured externally characteristic ulcerations occasionally develop. In these late syphilitic inflammations of joints there will frequently be found in the joint a gummatous or carious destruction of the bones and sharply defined circumscribed losses of substance, or radiating, glistening white cicatrices in the cartilage, together with fibrillation of the latter, while in other instances a connective-tissue growth in the synovial membrane, taking the form of indurations or of villi, may be more prominent. The pathological changes at the first glance sometimes look like those which occur in arthritis deformans. Many cases run a course with a very gradual increase in the amount of swelling, and resemble clinically tumor albus, but the pathological changes are very different from those of tubercular arthritis. In rare instances the gummatous nodes occur in the synovial membrane in a miliary form and may be macroscopically mistaken for tubercles, and then only a microscopic examination and other manifestations of syphilis which may be present will clear up the diagnosis. The indurated, villous connective-tissue growths, the losses of substance and the cicatrices in the cartilage, and the gummatous, carious destruction of bone are characteristic of

syphilitic disease of joints. An acute, subacute, or chronic serous arthritis may also occur in the later stages of syphilis, and primary suppurative inflammation of a joint will be encountered in rare instances —for example, when syphilis is complicated with gonorrhœa, etc.

The therapy of the syphilitic inflammations of joints consists, in the first place, in a proper local treatment conducted according to the rules which have been given for diseases of joints, and, secondly, in a general antisyphilitic treatment, the best being inunctions of ungt. hydrarg. ciner. (see § 84, Treatment of Syphilis).

VI. **Arthritis Deformans or Malum Senile.**—This affection is in every respect the opposite of tubercular arthritis. Suppuration or caries never occurs. The disease attacks individuals who are old or past the prime of life, and almost always involves several joints. As a rule, it causes deformities in the joints, which very gradually become more marked, while recovery—i. e., a complete *restitutio ad integrum*—never occurs, and arrest of the process only rarely.

The *pathological changes* which take place in arthritis deformans consist (1) in degenerative processes in the cartilage and bones, and (2) in hyperplasia of the bones, cartilage, and soft parts. A fibrillation occurs in the more superficial layers of the ground substance of the hyaline cartilage, while a localised cracking and softening are produced in the deeper layers by the vascular medullary spaces of the underlying bone pushing their way into the cartilage. At the same time, particularly at the free borders, a growth of cartilage occurs taking the form of knob-like tuberosities, which subsequently, for the most part, ossify (Figs. 377, 379). In consequence of the degenerative fibrillation and softening of the cartilage (arthritis chronica ulcerosa sicca) the latter may completely disappear, exposing the uncovered bone, which then, by the friction produced in the movements of the joint, develops a smooth, polished surface (Fig. 379, *a*).

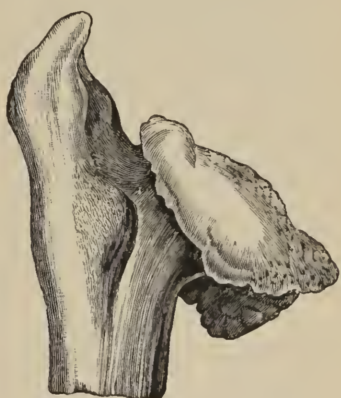


Fig. 377.—Coxitis deformans: head of the femur below the tip of the great trochanter; neck of the femur no longer present (Path. collection in Zürich—Volkmann).

The degenerative changes which take place in the bone consist in a lacunar absorption and inflammatory atrophy of the bone tissue, for the most part subchondral. The atrophy of bone is occasionally very considerable, and may lead to the disappearance of the head or entire neck of the femur (Figs. 377, 378).

Just as in the case of cartilage, there will be encountered in addition to the atrophy a new formation of bone which is sometimes very marked (Figs. 378, 379). In some cases the atrophy of the bone predominates (Fig. 377), in others the new formation of bone (Fig. 379). These degenerative and hyperplastic changes in the cartilage and bone are very characteristic of arthritis deformans. The capsule and ligaments of the joints also become thickened and afterwards contracted, and the synovial villi become the seat of an active process of proliferation. Loose-joint bodies (see § 115) are very frequently found in the joint, but adhesions between the articular surfaces of the bones or obliteration of the joint by newly-formed connective tissue almost never occur.

Fig. 378.—Arthritis deformans of the hip joint: the greatly enlarged head of the femur lies very near the trochanter owing to the disappearance of the neck (Path. Institute at Leipsic).

The joints gradually become so deformed by these changes in the articular ends of the bones and by the thickening and shrinking of the capsule, which is sometimes the seat of a new formation of bone, that motion becomes more or less limited or entirely lost. If the atrophic changes in the bones predominate the joint may become abnormally mobile or even loose and flail-like, with a tendency towards subluxation or complete dislocation (luxations of deformity, as they are called). These dislocations cannot, as a rule, be kept permanently reduced owing to the deformities of the head of the bone and the socket, and in the case of dislocations of the head of the femur a new acetabulum may be formed on the ilium (Fig. 380).

Arthritis deformans is most commonly observed in the hip, knee, elbow, and shoulder, and less often in joints of the fingers and vertebræ. In the vertebræ the atrophy of bone may cause the development of spinal curvatures, especially kyphosis, while the new formation of bone may give rise to osseous union between the different vertebræ. Arthritis deformans is either monarticular or polyarticular. If monarticular, it is usually located in a large joint, while the polyarticular form more commonly occurs in the small joints, such as those of the fingers or toes, etc.

We still know little about the etiology of this disease, though its anatomical peculiarities are so characteristic. It may begin spontaneously, or follow the reception of some traumatism, such as a fracture which involves the joint, or come on after some such infectious inflammation as a gonorrhœal arthritis, or after acute polyarticular rheumatism. The patient's occupation or position in life plays no part in the causation of arthritis deformans, but his age probably does. I look upon this affection as essentially a senile disorder which, as a rule, can be traced to some exciting cause, such as a traumatism or an infection—it is rarely spontaneous — and gives rise to characteristic atrophy and to hyperplasia of the cartilage and bone, and to thickening and contraction of the capsule.

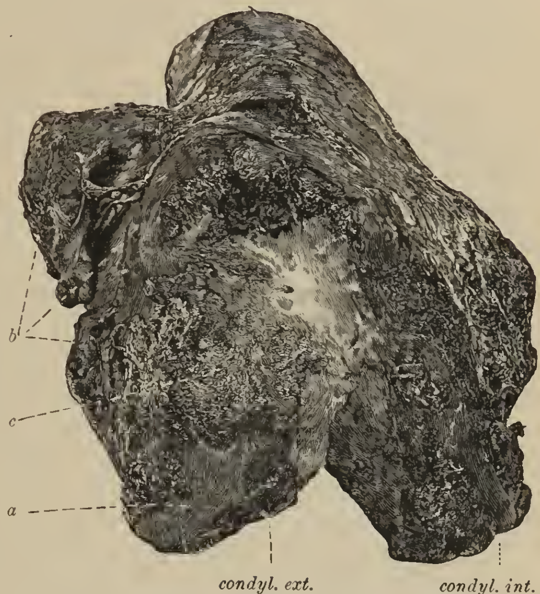


Fig. 379.—Arthritis deformans of the right knee-joint: *a*, polished and smooth articular surface; *b*, growth of bone and cartilage; *c*, fibrillation of the cartilage; unequal length of the femoral condyles, giving rise to pronounced genu valgum; the transverse diameter of the internal condyle and the longitudinal diameter of the external condyle are shortened (Path. Institute at Leipsic).

The *clinical course* of both the monarticular and polyarticular form of arthritis deformans is exceedingly chronic, and it is not an uncommon thing for the disease to last twenty to thirty years. The initial symptoms are those of a chronic arthritis running a course without fever, and consist in stiffness of the joint, particularly in the morning hours, in slight pains, and in the occurrence of crepitating or creaking sounds. Later on the deformities of the articular ends of the bones or of the entire joint become prominent. The movements of which the joints are capable become more and more restricted, or the opposite condition may exist, the joints becoming loose and flail-like. Occasionally acute inflammatory symptoms make their appearance, consisting of fever, increased tenderness and inflammatory swelling of the joint, and an acute effusion of serum. The pain may be excessive. Recovery is extremely rare, the disease ordinarily growing worse very

gradually until it is terminated by death from some intercurrent affection.

Diagnosis.—The very chronic course of the disease, the absence of suppuration and caries, the characteristic deformity of the joints, the advanced age of the patient, and the history of some predisposing cause, are important factors in the diagnosis of arthritis deformans.

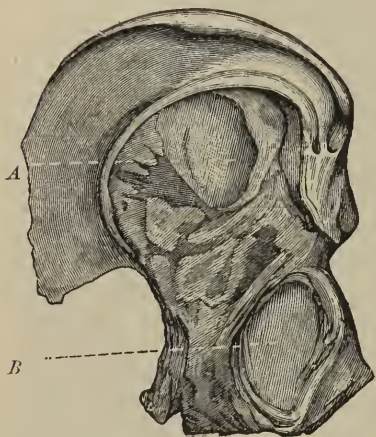


Fig. 380.—Formation of a new acetabulum (*A*) on the os ileum after a dislocation from arthritis deformans in a woman seventy years old; *B*, remains of the original acetabulum (Gutsch).

The Treatment of Arthritis Deformans.—The sooner arthritis deformans is subjected to systematic treatment by massage and active and passive movements of the joint, the greater is the possibility, particularly in the case of the monarticular form, of arresting the further development of the disease. In addition to massage and methodical exercise of the joint, baths in which the entire body is immersed in lukewarm water, or sand baths, mud baths, or steam baths, combined with cold douches—in short, hydrotherapeutic measures—are especially to be recommended. The use of hot springs, such as Gastein, Wildbad, Wiesbaden, Teplitz, Ragatz, etc., and a residence in southern climates, are also exceedingly serviceable. Marked disturbances of function, especially in the upper extremity, can be improved by performing resection, but amputation is only indicated in the rarest instances, where the changes are very pronounced. Resection of the joint has been repeatedly practised for severe pain, the results in some cases being excellent, and in others entirely negative (Fock, Küster, Riedel, etc.). The other complications, such as the acute exacerbations, dislocations, or flail-like joints, which sometimes occur, are treated according to the general rules which apply to these conditions. The internal administration of drugs, such as iodide of potassium, aconite, quinine, iron, etc., is of little use, but a strengthening mode of life with nourishing food, fresh air, etc., is very important.

The Diseases of Joints which occur in Bleeders (*Hæmophilia ;* see page 57). —Individuals who suffer from hæmophilia are sometimes affected by various kinds of joint diseases, which generally take on a serious character owing to the presence of the constitutional dyscrasia. Leaving out of consideration the different forms of inflammation of joints which occasionally occur in

bleeders as well as in other people, there is left a certain definite group of joint diseases which are clinically and pathologically peculiar to hæmophilia, and which are to be regarded, so to speak, as a symptom of this disease. König has recently described "bleeder joints" very much at length, and I can fully confirm his statements. These typical joint diseases which are met with in hæmophilia are characterised by the presence in the joint of an effusion of blood, which may persist in an unaltered state for weeks and then gradually grow smaller, and, if the conditions are favourable and compression is employed, may eventually entirely disappear. But in other instances, particularly if the disease is not properly treated, the effusion of blood is added to by fresh hæmorrhages, the joint becomes gradually more and more damaged, the articular cartilages undergo erosion and fibrillation, and the joint grows constantly stiffer, finally becoming obliterated. If the unfavourable conditions continue, contractures and deformities of the joints develop. It is a very easy matter to mistake a bleeder joint, particularly during the early stages, for hydrops tuberculosus. König lost two patients from hæmorrhage because he had thought the articular disease was tubercular and consequently undertook extensive operations. In making the diagnosis of a bleeder joint the personal history of the patient is of the utmost importance, for the reason that the patients or their parents are generally aware of their bleeder disease. It should be noted that it almost always occurs in young subjects, the large effusion of blood usually develops suddenly from some slight traumatism, pain is generally absent, and several joints are commonly affected, some being in the early and others in the advanced stages.

The *treatment* of recent cases consists in placing the limb in an elevated position, in immobilisation and compression of the joint, and subsequently in gentle massage and passive motion. In some instances the joint should be punctured for the purpose of removing the effused blood. Massage should be used cautiously and as an experiment.

§ 115. **Joint Bodies or Joint Mice** (*Mures Articulares*).—By joint bodies or the so-called joint mice (mures articulares) we mean bodies varying in structure which are formed within joints and are either free or attached by pedicles. Joint bodies anatomically consist of cartilage or of bone, or of bone with a cartilaginous covering, of fibrous connective tissue, of fatty tissue, or of masses of fibrin.

We are able to distinguish etiologically three principal kinds of joint bodies: (1) Concretions made up of fibrin, (2) joint bodies resulting from the breaking off of cartilaginous or bony portions of the articular ends of the bones or intra-articular ligaments by some traumatism, and (3) growths of connective tissue, cartilage, or bone which originally are pedunculated, but later, as a result of atrophy or sudden rupture of the pedicle, become free joint bodies.

The fibrin concretions—i. e., the fibrin precipitated from the synovia in cases of chronic hydarthros, for example—take the form of round, smooth, or irregularly shaped concrements, usually about the size of a

melon seed or grain of rice, which often occur in great numbers. These concrements, from their similarity to grains of rice, are also called rice bodies (corpora oryzoidea). Schuchardt maintains that the rice bodies are not "fibrinous" products of coagulation formed from the thickened contents of a joint or tendon sheath, but are portions of the synovial membrane or tendon sheath which have undergone coagulation necrosis (Weigert) or fibrinoid degeneration (Neumann). Occasionally the concrements attain a considerable size—that of a hen's egg, for example, or larger. Small foreign bodies, such as needle points, broken-off synovial villi, a blood-clot, etc., have been found in the interior of the concretions, just as in vesical calculi.

In the second category of cases the free joint bodies are formed from bony or cartilaginous portions of the articular ends of the bones or intra-articular ligaments which are torn from their attachments by some traumatism, such as a blow, a fall, or some other violence. These may be increased in size, partly by deposits of fibrin from the synovia and partly by the independent growth of the cartilage or medullary cells which they contain. Occasionally the detachment is not complete, and then at some later period there takes place a gradual or sudden separation of the partially detached piece of bone or cartilage. Kragelund was able only by using a great amount of force to partially or completely break off from the femur—generally the internal condyle—but not from the tibia, portions of bone which presented a close similarity to mures articulares, and Poncet saw small fragments of bone torn from the points where the ligaments were attached.

Furthermore, without the reception of any traumatism or injury, larger or small pieces may become separated from the articular ends of the bones as a result of some process which is not as yet understood; these pieces are then covered on their bony surfaces with dense connective tissue which contains cartilage cells, and the loss of substance in the bone from which they came is repaired in a similar manner. König has given the name of *osteochondritis dissecans* to this genetically obscure and circumscribed disease of the articular ends of the bones.

The third way in which joint bodies may originate—i. e., in the form of steadily enlarging growths of tissue attached by a pedicle to some part of the articulation, such as the villi, the synovial membrane, or the articular cartilages—is met with especially in chronic joint diseases, such as arthritis deformans, or hydarthros chronicus, or after fractures which involve the joint. The growths are made up, according to the point from which they spring, of connective tissue, cartilage, or bone, or bone with a cartilaginous covering, and then by gradual atrophy or by sudden rupture of the pedicle these growths become free joint

bodies. In this category belong the free joint bodies formed by growth of the synovial villi or by fibrillation of the cartilage, as well as those which result from the detachment of tumours of cartilage or bone (enchondroma osteoma), or of the cartilaginous or bony plates in the synovial membrane which may develop in the course of hydarthros and arthritis deformans. As a result of the fibrillation of the articular cartilage occurring in a chronic arthritis, there is often a very excessive formation of cartilaginous villi in which a vigorous circumscribed growth of cartilage cells sometimes takes place. If these formations become loose, hyaline rice bodies analogous to the above-mentioned fibrinous rice bodies develop, having exactly the same form as the latter, and likewise existing in very great numbers. The condition in which there is an excessive growth of fat in the villi is called *lipoma arborescens*, and may give rise to the formation of free joint bodies which are soft and made up of fat. The cartilaginous and bony joint bodies vary greatly in size, some being not larger than a bean or almond, while others are as large as the patella. Billroth states that a joint body has been preserved in the museum at Vienna as large as the os calcis, which was found attached by a pedicle to the capsule of the joint.

Symptomatology and Diagnosis of Free Joint Bodies.—As we stated before, joint bodies are found in joints which are either otherwise perfectly healthy or are the seat of chronic inflammation, particularly chronic hydarthros and arthritis deformans. The knee joint is the most common location in which they are encountered, while of the other joints the elbow comes next. The symptoms caused by free joint bodies are, first of all, a sudden, severe, darting pain, experienced during some particular movement of the joint, often causing the patient to appear as though paralysed and to fall to the ground in a faint. These pains, which reappear with more or less frequency, are particularly likely to occur when a moderate-sized, freely movable joint body becomes caught in a synovial pouch or between the articular ends of the bones. The attacks of pain are usually followed by inflammatory manifestations in the joint of greater or less severity, which take the form of an acute serous synovitis.

Diagnosis.—These characteristic, paroxysmal pains are of the greatest importance for making the diagnosis of free joint bodies. In some instances the latter can be felt. Nevertheless, one can be deceived even in this, and I once mistook a commencing circumscribed tuberculosis of the capsule of the knee joint for a free joint body. After opening the joint and extirpating the diseased portion of the capsule, recovery took place, with perfect motion in the joint. The most difficult cases to recognise are those in which the joint bodies exist in

an articulation which has undergone changes due to arthritis deformans.

Treatment.—The best treatment for free joint bodies consists in their operative removal by aseptic arthrotomy. The body having been located by palpation, an incision is made directly down upon it, whereupon it is pressed through the opening thus made and the borders of the wound are immediately closed by sutures. The joint is then immobilised as completely as possible with an antiseptic protective dressing, over which splints are placed. If the patient is afraid of the knife, or if the condition does not cause him much trouble, we recommend the wearing of an elastic cap around the joint, to afford the latter a certain amount of support and prevent too free motion. In those cases where the symptoms indicate beyond a doubt the presence of a joint body, but where, as in the elbow, it cannot be reached by an incision made directly down upon it, in case the patient's discomfort is great enough, the joint should be laid freely open with the strictest aseptic precautions, and, if necessary, a partial (temporary) resection undertaken to render it possible to remove the joint body.

Exostosis Bursata with Joint Bodies.—Bergmann operated upon an exostosis on the outer aspect of the lower end of the femur, just above the knee, which was surrounded by a capsule containing upwards of five hundred rice bodies made up of hyaline cartilage. The exostosis probably originated intra-articularly as an ecchondrosis of the articular cartilage, and derived a true synovial sac by pushing before it the capsule of the joint, the diverticulum thus formed becoming afterwards completely shut off from the joint. In other instances the exostosis has been found still in the joint, as in a case of Volkmann's, where it was attached to the portion of the semilunar cartilage which adjoins the capsule. In this case there were in addition three bodies lying free in the joint (see Exostoses, § 128).

§ 116. **Neuroses of Joints (Neuralgias of Joints; Nervous, Hysterical Diseases of Joints).**—The nervous or hysterical affections of joints, the neuroses or neuralgias of joints, were first described by the celebrated English surgeon Brodie, and his statements have been confirmed by such German surgeons as Stromeyer, Esmarch, and Erb; while quite recently Newton M. Shaffer has written an exhaustive treatise on the subject. No pathological changes can be made out in joints which are the seat of neuralgias. The knee and hip are the ones most commonly affected, and usually one joint at a time, rarely two or more. Females with an over-excitable nervous system, or who are markedly hysterical, especially young girls of the better classes of society, are particularly apt to suffer from these troubles, and hence the term hysterical joint affection. But the disease is occasionally met with even in perfectly

healthy men and women. Among the exciting causes may be mentioned traumatisms, such as bruises and sprains of the joints, irritation of or pressure upon the nerves in the neighbourhood, excessive emotional disturbances, and taking cold. Joint neuralgias also occur reflexly from diseases of the abdominal viscera, especially the female sexual organs, and from diseases of the central nervous system, such as tabes.

Symptoms and Course of Joint Neuroses.—The chief symptom of a joint neuralgia or neurosis is the pronounced pain and tenderness in the joint, while objectively nothing abnormal can be made out. The pain is felt especially when pressure is made at some particular point, or when the joint is moved. In addition to these tender points, there is generally a pronounced diffuse hyperæsthesia of the skin over the joint; but in rare instances there may be anæsthesia. Moreover, the function of the joint in question is disturbed—i. e., the patient avoids moving the joint because of the pain, and keeps it rigid. There are also observed a state of muscular spasm, with secondary distortions of the joints (contractures); vasomotor disturbances (urticaria-like wheals, alternate flushing and blanching, etc.); tremor; a marked feeling of weakness; atrophy of the extremity which is involved, and now and then paralyses. The stiffness and contractures of the joints, which may take the form of nervous club-foot or stiffness of the hip, will immediately disappear under chloroform anæsthesia, and while the patient is in this state the joint will be freely movable. The vertebral column, especially the spinous processes, are also sometimes tender on pressure. The course of the nervous joint affections is usually rather tedious and very variable. If the nervous system is otherwise normal, recovery generally takes place after the lapse of a longer or shorter time, though it may occur suddenly after some emotional excitement or after some energetic movements have been made with the joint. In cases of pronounced hysteria, or diseases of the nervous system, the patients are occasionally doomed to be confined to bed for years, and in such instances the affection is often incurable.

In making the diagnosis of a hysterical joint, we should note particularly that certain symptoms which indicate an inflammation of the joint are absent, and that the contractures, the stiffness, etc., disappear completely under chloroform anæsthesia. The above-mentioned manifestations of the disease are so characteristic that they are generally sufficient to establish the diagnosis. Old sprains with slight intra-articular adhesions have sometimes been mistaken for joint neuralgias; but cases of this kind can be cured in a very short time by massage combined with forced movements of the joint.

The prognosis is favourable in the case of individuals who are

otherwise healthy; but if they are excessively neurotic and hysterical, it is uncertain, and is the more unfavourable the severer the nervous complications.

Treatment.—The treatment of nervous joint affections is directed first of all towards the cause. If there is pronounced neurasthenia, hysteria, or other nervous anomalies, or disease of certain organs (of the sexual organs, constipation, etc.), these conditions must receive careful attention. In every case a general tonic treatment for the nervous system by cold-water cures, sea-bathing, a sojourn in the mountains, and removal of the patient from his business and family, are very much to be recommended. Treatment of a psychical nature is also very valuable; while unexpected joy or sorrow has often caused hysterical joint neuroses to disappear suddenly and permanently. The local treatment of the diseased joint comprises massage and methodical exercise, rubbing with cold water, and electricity (the strong faradic or galvanic current passed transversely through the joint). Morphine or atropine is occasionally given in the form of subcutaneous injections if the patient is otherwise healthy and robust. Quinine and arsenic, given internally, are also of use. For the contractures and the weakness of the muscles and joints we employ suitable braces or splints which will enable the patient to move his limbs.

Other Joint and Bone Neuralgias.—The neuralgias sometimes occurring in joints and bones which have previously been the seat of a disease like tubercular arthritis, or which make their appearance in the course of syphilis, or after recovery from caries and necrosis, or in general occur in old bone cicatrices, are of a totally different nature. Pain of this description is very apt to occur in syphilis, or in ossifying osteomyelitis and periostitis, or in sclerosis of bone. The treatment of these joint and bone neuralgias depends upon the cause. Warm baths and the bathing cures given at Teplitz, Wiesbaden and Gastein are generally very useful. The pain occurring in bones and joints which have been at one time diseased may sometimes become so severe that amputation or disarticulation is performed at the patient's own request. Close examination of the bone in such cases reveals nothing which can account for the great suffering, but we do find that individuals thus affected are usually neurotic (Poncet, Auday).

Quite often, however, these neuralgias are due to circumscribed, inflammatory foci concealed in the bone or joint, and if this is the case the disease should receive its appropriate treatment. Abnormal adhesions in a joint, such as may occur, for example, in old dislocations which have been improperly treated, may give rise to violent pains, which can be quickly stopped by massage and exercise. In general, neuralgias of joints and bones following a pre-existing disease are most commonly the result of syphilis or some nervous disease; and these must be the first things to be considered in the treatment.

Sometimes violent pain also occurs in bones which are otherwise ap-

parently healthy and have not previously been diseased, coming on especially after taking cold, and in neurotic individuals. Warm baths and the use of the above mentioned hot springs, as well as an antineurotic treatment, should be employed.

§ 117. **Neuropathic Diseases of Bones and Joints.**—Peculiar neuropathic affections of the bones and joints, of great clinical interest, occur in the course of diseases of the nerves and spinal cord, especially tabes. Charcot was the first to describe accurately the arthropathies which make their appearance during the course of the grey degeneration of the posterior columns of the cord; and while Charcot, Erb, Buzzard and other neurologists ascribe the arthropathia tabidorum to direct nervous influences—in other words, to trophoneurotic disturbances—Volkmann, Leyden and Virchow maintain that the tabes merely brings about unfavourable conditions, in consequence of which certain diseases of the joints occur more easily and frequently than they do in a state of health, and run an unusual and malignant course. The main predisposing causes in tabes of inflammations and injuries of the bones are the loss of sensibility—i. e., the anæsthesia or analgesia of the joints, the ataxia, and the fragility of the bones. These factors also influence very materially any deforming or traumatic, acute or chronic inflammation occurring in a person suffering from tabes dorsalis. The softness and brittleness of the bones in tabes are well known, and account for the frequency with which spontaneous fractures take place in patients with this disease. The fragility of the bones is due to a trophoneurotic change in their organic ground substance, and may be encountered even in bones which are apparently very strong and compact. The bones may also become remarkably brittle in people with various mental diseases, or with infantile spinal paralysis, progressive muscular atrophy, leprosy, etc., and Neumann has ascribed the changes that occur to an affection of the vasomotor system. Czerny, Rotter and others have lately made exhaustive studies of arthropathia tabidorum and neuropathic bone and joint affections in general. The question of the relationship between these affections and the sclerosis of the posterior columns of the cord and other diseases of the spinal cord and peripheral nerves has recently been the subject of animated discussion, but as yet it has not been positively decided whether spinal diseases, such as tabes, syringomyelia, etc., should be regarded as direct causes of these troubles, which Charcot believes them to be, or only as predisposing. Charcot has lately adopted the view that they are due to certain localised processes of disease in the diaphyses and epiphyses.

Cause of Arthropathia Tabidorum.—As before stated, the anæsthesia

or analgesia of the joints plays a most important part in the production and course of arthropathia tabidorum. The neuropathic affections of the joints which occur in tabes begin either without any external cause, or they follow the reception of some traumatism; and as the patients feel no pain, they walk about while their joints are inflamed and thus make matters worse; they wear off the brittle articular ends of the bones, as it were, so that the entire astragalus, for example, may by degrees completely disappear. A tabetic individual with a fracture of the leg, who came under Volkmann's care, could produce a very marked displacement of the fragments without suffering any pain. The analgesia cannot always be easily recognised, it being occasionally limited to the more deeply situated nerves alone, while the skin is even over-sensitive to the slightest irritation. The chronic arthropathies which occur in tabes and do not go on to suppuration, run, as a rule, a course similar to arthritis deformans (see page 683), but differ from the latter in the fact that the different parts of the joints are very rapidly destroyed, and dislocations and spontaneous fractures are of frequent occurrence. One can distinguish, as in arthritis deformans, an atrophic and a hypertrophic form of arthropathies as well as a monarticular and a polyarticular form. If the specific excitants of inflammation—micro-organisms—gain entrance to a joint of this kind which is the seat of a chronic inflammation, septic or even gangrenous inflammation running a very rapid course often develops. Hence it can be seen that in the course of tabes various forms of arthritis may be encountered, some acute and others chronic, and either suppurative or non-suppurative; but the characteristic feature of the inflammation is that it is always greatly modified and influenced by the analgesia and ataxia which are present, and by the weakness and fragility of the bones. The knee is the joint most commonly affected, although the articulations of the upper extremity do not always escape. Rotter has collected 112 cases of joint disease occurring in 74 patients with tabes; of these, 49 were of the knee, 24 of the hip, 12 of the shoulder, 12 of the tarsal joints, 6 of the elbow, 4 of the ankle, 3 of the hand and fingers, and 2 of the temporo-maxillary joint. Both knee joints were diseased in 11 cases, both hips in 7, the tarsal joints in 3, and the shoulder, wrist, and finger joints were symmetrically affected twice. In Weizsäcker's statistics of 109 cases, 72 occurred in men and 37 in women. The knee joint was affected 78 times, the hip 31, the shoulder 21, the tarsus 13, the elbow 10, the ankle 9, the carpal and temporo-maxillary joints twice, and the vertebral column once. The observations of Leyden, Oppenheim and others show that affections of the joints and weakness and fragility of the bones may

occur in both the earliest and the most advanced stages of tabes dorsalis.

In making the *diagnosis* of neuropathic bone and joint affections, the characteristic features in chronic cases are the existing nervous disorders, which in the case of arthropathies of the lower extremity is most commonly tabes, and of the upper extremity syringomyelia, the analgesia, the pronounced exudation, and the marked destruction of the articular surfaces of the bones ; the acute cases become rapidly worse. Czerny is right in calling attention to the fact that the predisposition to nervous disorders is an important matter from a medico-legal standpoint—in other words, should be taken into account in a plaintiff who brings suit for damages.

The *prognosis* of the tabetic arthropathies is very uncertain, and depends largely upon whether the joints are used or protected and properly treated, whether ataxia exists, etc. If proper treatment is received (fixation, orthopædic appliances, etc.), it is possible for the arthropathy to be improved or arrested.

Similar neuropathic affections of the bones and joints are also noted in the course of other cerebral and spinal diseases and are due to analogous disturbances of innervation. In six cases of neuropathic joint disease described by Czerny, two of the patients suffered from tabes and four from syringomyelia (see below). If the upper extremity is the seat of paresis and analgesia, affections of its joints may occur which run the same course as the arthropathies of tabes; there may also be a grinding away of the head of the humerus in the shoulder joint, spontaneous fracture of the bones of the forearm, osteophytic growths, trophic disturbances in the skin (ulcers), etc. Neuropathic contractures are discussed on page 701.

The Arthropathies of Syringomyelia.—The arthropathies coming on in the course of syringomyelia mainly attack joints of the upper extremity, for the reason that the primary disease is for the most part localised in the cervical portion of the spinal cord, and they occur in the great majority of instances in men of advanced age. Traumatisms play a predisposing part in their production. The course of the arthropathies is always chronic, not infrequently lasting for years. There will occasionally be observed an acute exudation in the joint, or even suppuration, especially if there has been some injury which on account of the analgesia has been neglected; but there seldom occurs such a marked destruction of the joint in a comparatively short time as in tabes. The changes in the joints are more like those of arthritis deformans, with the formation of intra-articular and periarticular osteophytes, with ossification of the periarticular soft parts, degeneration of the muscles, and thickening, dilatation and relaxation of the capsule, with secondary spontaneous dislocations. The joints are analgesic, and sometimes to such a pronounced degree that large joints can be resected without chloroform (Czerny, Sokoloff). This

analgesia is, moreover, the chief factor in furthering the development of the disturbances of nutrition which are present in the joints and bones. The bones are in some instances abnormally weak (hence the spontaneous fractures) and in others remarkably sclerotic. The termination of the arthropathies which occur in syringomyelia is governed mainly by the primary disease in the spinal cord, and also by the amount of care the patient takes to protect his joints from injuries that may readily give rise to complicating periarticular and intra-articular suppuration. Under favourable conditions the joint affections are usually very protracted. The diagnosis can be readily made if the pathological changes and the clinical course are taken into consideration together with the analgesia and the location of the arthropathies in the upper extremity. The treatment, particularly in the early stages, consists in immobilising the joint, though later on suitable operative measures may be necessary, as they are in tabes.

The *treatment* of the neuropathic inflammations of joints, particularly the arthropathies which occur in tabes and syringomyelia, comprises proper local treatment of the affected joint and general treatment of the neuropathy which is the primary cause of the trouble. We consider, as Czerny does, that firm anchylosis in a good position is preferable to a loose joint which is rapidly ground to pieces by friction, and in the early stages it would be proper to bring about artificial anchylosis by performing arthrodesis (see page 133). If patients with the above-mentioned diseases of the spinal cord receive a sprain, the joint must be treated by immobilisation and subsequently by a supporting apparatus. Should extensive destruction or suppuration of the joint occur, the question of arthrotomy, resection or amputation would arise.

§ 118. **Anchylosis.**—By anchylosis (from ἄγκυλος, angular, crooked) is understood an immovable, stiff joint, such as results from an inflammation of a joint which has run its course. The word anchylosis signifies properly an angular position of the joint; but this conception of the term has in course of time been entirely given up, so that when we speak of anchylosis of a joint we mean that its power of motion has been lost, irrespective of whether the joint has become fixed at an angle or in a straight, extended position. If a joint is in an angular position we speak of it as a *contracture* (see § 119). Anchylosis—in other words, stiffness of the joint—and contracture very frequently occur in combination. If we wish to differentiate these two terms more exactly, we may say that *anchylosis* signifies a complete cessation of the motility of a joint brought about by intra-articular causes, while *contracture* is a limitation of motion generally due to pathological changes in the extra-articular soft parts (see all § 97 and § 98, Diseases of the Nerves and Muscles). We also recognise a false and a true anchylosis (anchylosis spuria and anchylosis vera). The term false anchylosis applies to those

cases in which apparently immovable joints can be caused to move under chloroform anæsthesia, and is a condition which is observed in the course of acute or chronic inflammations of joints, or as a result of inflammatory or voluntary muscular contraction, or in hysterical joint disorders, etc.

The Causes of True Anchylosis.—True anchylosis is most commonly due to the development of a firm union between the different parts of the joint, and according to the nature of the tissue forming the union between these parts we recognise a connective tissue (anchylosis fibrosa), a cartilaginous (anchylosis cartilaginea), and a bony anchylosis (anchylosis ossea). The cicatricial connective tissue which develops between the opposed articular surfaces in the healing, for example, of an arthritis with fungous granulations, either takes the form of adhesions which resemble ligaments, or they more or less completely fill the joint. If ossification of the connective tissue takes place it is possible for a bony anchylosis to occur, in which case the articular ends of the bones are joined together by an osseous bridge, or united by bone throughout their entire extent. Bony anchylosis may develop from the cartilaginous form, or it may arise from the direct coalescence of joint surfaces which have lost their covering of cartilage. Cartilaginous anchylosis is brought about by a growth of vascular connective tissue between the opposed surfaces of the articular cartilages, and if, then, this connective tissue disappears, the surfaces of the cartilage are found to have coalesced into a single cartilaginous mass. Other causes of stiffness in joints are cicatricial shrinkage of the capsule and ligaments of the joint, and adhesions between two opposed portions of the synovial membrane, so that the latter can no longer adapt itself to the movements of the different portions of the joint. Anchylosis may also be caused by the growth of bone or cartilage in a joint, as in arthritis deformans, or by the development of bone in the capsule or parts surrounding the joint, which sometimes occurs after fractures in the neighbourhood of or extending into a joint. Furthermore, the articular ends of bones may be so altered by changes such as occur in caries and arthritis deformans that they do not fit together, and so are not capable of performing their function of gliding over each other (anchylosis of deformity). We learned in a previous chapter that joints may become fixed in a faulty position by muscular contractures, or by cicatricial processes in the muscles, tendons, tendon sheaths, bones, etc.

It is generally an easy matter to make the diagnosis of anchylosis, but in doubtful cases chloroform anæsthesia may be required to determine whether the anchylosis is false or true; it is also the best way of finding out how much motion, if any, exists.

Treatment of Anchylosis.—The treatment of a stiff joint includes both an attempt at restoration of its motion and at overcoming the abnormal position in which the joint may have become anchylosed; in other words, one should strive to place the joint in such a position that the limb may be more or less useful to the patient. Only in rare instances is it possible to restore motion in a joint which has become fixed by true anchylosis, and then it is generally accomplished by resection. But we can very often prevent an anchylosis from taking place by employing proper treatment for the diseases and injuries of the joints and the parts which surround them, particularly by causing wounds to heal aseptically, and after the subsidence of inflammation, by using massage and active and passive motion. If in the course of an injury or inflammation of a joint we are unable to prevent an anchylosis from developing, we must always place the joint in that position which will render it most useful for the patient—the knee, for example, in extension, the ankle and elbow at a right angle, etc. If the joint has already become fixed in a distorted position, it may be possible to gradually overcome the latter by massage and passive motion, by manual correction under anæsthesia, by permanent extension by a weight, by the use of frequently applied plaster-of-Paris dressings or splints which exert pressure or traction, or by operative division of the contracted periarticular soft parts, especially the muscles, tendons, and fascia (see Tenotomy, Myotomy, page 558), by osteotomy of the bone in the neighbourhood of the joint, or by resection of the joint, combined possibly with the removal of a wedge of bone. Osteotomy is performed either in the form of simple division of the bone (see § 26), or division combined with the removal of a wedge-shaped piece from the continuity of the bone. Volkmann's method of performing linear or wedge-shaped osteotomy below the trochanter of a hip which has become anchylosed has yielded excellent results, improving both the position and the usefulness of this joint. Resection of the joint (§ 40), and in desperate cases amputation or disarticulation (§ 36 and § 37), are also operations which may have to be resorted to. When there is a firm anchylosis due to fibrous, cartilaginous or bony union between the articular ends of the bones, combined with a distorted position of the joint, resection of the latter is generally called for, the object being the formation of a movable joint, or one fixed in a position which will render use of the limb possible. The operation of arthrodesis for obtaining artificially anchylosis of a paralytic, flail-like joint is described in § 40.

§ 119. **Deformities of Joints (Contractures).**—The deformities of joints which we shall speak of here are faulty positions in which joints

may have become more or less fixed, and are sometimes congenital and sometimes acquired, and when acquired are called contractures. In discussing the subjects of inflammation and anchylosis of joints we learned how contractures might develop, and consequently we shall confine ourselves at present merely to a brief account of the individual forms of this affection, the reader being referred to the Special Surgery for a more detailed description of each, especially as regards the treatment.

The *congenital* deformities of joints are mainly due to disturbances of development which occur in the fœtal stage of life. The congenital club-foot (pes varus, Fig. 381)—i. e., the supination-contracture of the foot—is an example of this. The supination is almost always combined with plantar flexion (pes equino-varus). It might be said that a slight amount of club-foot is physiological, inasmuch as every infant at birth has some suggestion of it. Pronounced club-foot is, briefly speaking, a disturbance of development in the astragalo-crural, the calcaneo-astragaloid, or the astragalo-scaphoid joints, which is brought about principally by the foot being kept in continuous supination owing to lack of space in the uterus. The bone which undergoes the most pronounced change of form in consequence of this continual supination of the foot *in utero* is the astragalus, the neck of which becomes longer than it normally should be, and somewhat bent; in other words, the growth of the astragalus adapts itself to the abnormal position which the foot assumes *in utero*. The rare cases of congenital flat-foot (pes valgus or planus, Fig. 385) and of pes calcaneo-valgus originate in a similar manner, being due to the pressure exerted by the walls of the uterus. By pes calcaneo-valgus is understood a foot which is dorsally flexed to such an extent that its dorsum comes nearly or quite in contact with the leg, and is at the same time abducted (Fig. 388). Scoliotic or kyphotic curvatures of

Fig. 381.—Club-foot (pes varus).

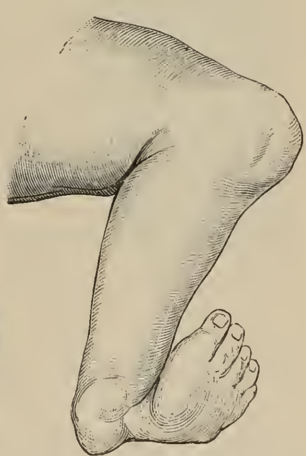


Fig. 382.—Club-foot caused by a congenital absence of the entire tibia.

the spinal column, or club-hand or club-foot, may also have their origin in congenital defects occurring in the vertebræ or in the bones of the forearm or (lower) leg (see Fig. 382).

The *acquired* deformities of joints are due first of all to disturbances occurring during the growth of articular surfaces previously normal, in children and young subjects. Thus deformities of the joints develop in the lower extremities and vertebral column as a result of the pressure exerted by the weight of the body. Their origin is to be ascribed to pressure on the joint surfaces, which is either too protracted or too excessive, or unevenly distributed. This class of cases includes the lateral curvatures of the spinal column or scoliosis (Fig. 383), genu valgum (Fig. 384), and flat-foot (pes planus or pes valgus, Fig. 385). Rhachitic bones are particularly apt to suffer from these pressure deformities; the pressure causes a gradual change in the shape of the bones, their growth being diminished in the parts where the pressure is greatest and increased where the pressure is least. The diaphyses or epiphyses of the long hollow bones, especially if they are soft (see Rhachitis), are thus bent and curved by the weight which they have to sustain. This is also the explanation of the change in the shape of the vertebræ encountered in a case of scoliosis which has existed for a long time, and of the curvatures of the femur and tibia in the neighbourhood of the junction of the epiphysis with the diaphysis; of the obliquity of the condyles in genu valgum (Mikulicz); and of the depression of the arch of the foot and change in shape of the tarsal bones in pes valgus. Stretching or shortening of the soft parts, especially the muscles, fascia, and the ligaments of the joint, may then develop secondarily.

Fig. 383.—Scoliosis.

As a result of primary disease of the muscles, or, more commonly, of the nervous system, myopathic and neuropathic deformities, or, in other words, true contractures of joints, are produced. Primary muscular contractures used to be thought very common, and were wrongly looked upon as the cause of scoliosis and flat-foot.

Neuropathic contractures are divided into the spastic and the paralytic. Spastic contractures are the result of diseases of the central nervous system, and hence belong more properly to the province of

internal medicine, so that we shall confine ourselves here to merely a brief description of them in so far as they are of surgical importance. Little and Erb have recently made a special study of this form of contracture, and have shown that it is not by any means as rare as has hitherto been supposed. Little has also given a description of a congenital spastic paralysis, of which Rupprecht has published some typical cases.

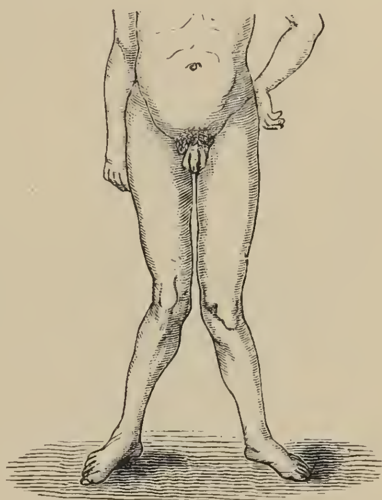


Fig. 384.—Genu valgum.

Spastic contractures (Fig. 386) are due in the main to a hyperinnervation of the muscles, and are either congenital, or acquired in the course of numerous diseases of the brain and spinal cord, such as tumours, embolism, localised infectious processes, injuries, spondylitis with compression of the spinal cord, chronic meningitis, hydrocephalus, syphilis of the brain, multiple sclerosis, and finally as a result of reflex action from simple irritation of the brain. Heusinger observed spastic contractures of the foot in the form of equino-varus during an epidemic of ergotism. The congenital form of spastic contracture (Erb's spastic spinal paralysis of children) is, according to Erb, due to pathological lesions which consist, as Little thinks, of interpartum hæmorrhages into the brain and spinal cord, resulting in sclerosis, chronic meningitis, and cerebromedullary hyperæmia.

Fig. 385.—Pes valgus.

The symptoms of spastic contractures are very characteristic. The muscles are not paralysed, but, on the contrary, possess an increased amount of innervation. As illustrated in Fig. 386, the tightly contracted muscles of the lower extremity compel the limb to assume a position of flexion, adduction, and inward rotation. The resistance which the muscles offer to an attempt at passive extension is usually very considerable. If, however, the patient sits or lies down, placing his body completely at rest, and if the points of origin and insertion

of the flexor muscles are approximated, the muscles immediately become relaxed. But every effort to use the muscles actively or to extend them passively, or any application of electricity, straightway gives rise to a tetanic contraction which renders co-ordinated movements impossible. Under chloroform the muscles of young persons become completely limp, and all movements can be easily made; but the muscles and ligaments on the flexor aspects of the limbs of older patients, as illustrated in Fig. 386, are ordinarily so shrunken that complete extension will no longer be possible.

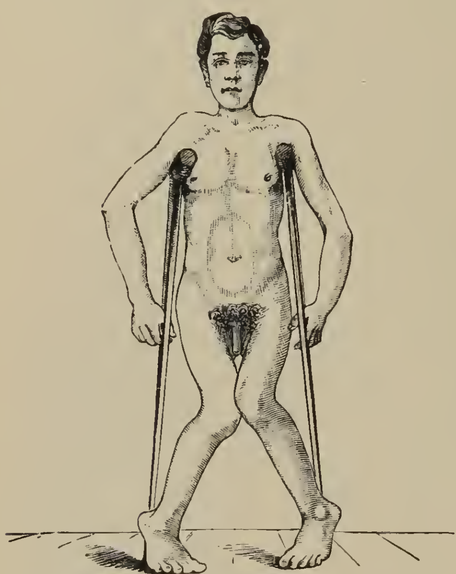


Fig. 386.—Spastic contracture of the lower extremities.

The paralytic contractures —i. e., those which are the result of paralytic conditions and follow injuries and diseases of the central nervous system and peripheral nerves — are extremely common (see Figs. 387, 388, 389). They include the paralytic contractures which occur so frequently with the partial or total paralyses following meningitis and encephalitis in children, and the spinal (so-called essential) infantile paralyses which affect almost exclusively the lower extremity. Of the paralytic contractures of the foot the most common are the pes equinus paralyticus (Fig. 387) and the paralytic club-foot which very often takes the form of pes equino-varus paralyticus. In the paralytic club-foot the equinus position predominates, but in the congenital form the varus contracture—i. e., the adduction and supination—is the most noticeable feature (Fig. 381). The pes calcaneus paralyticus (Fig. 388) and the pes valgus paralyticus (Fig. 385) are much rarer. Paralytic contractures of the knee, the hip, and especially of the hand, where they may follow injuries of the ulnar, median, or musculo-spiral nerves, are comparatively common. Fig. 389 illustrates the typical *main en griffe*, or claw position, assumed by the fingers after paralysis of the ulnar nerve. In the region of the spinal column paralytic contractures take the form of lateral curvatures (paralytic scoliosis) or of flexion or extension contractures (paralytic kyphosis and lordosis). In all cases paralysis of any one

particular group of muscles, or rather of the nerves which supply them, invariably gives rise to a characteristic contracture (see Special Surgery, § 294).

Fig. 387.—Pes equinus paralyticus.

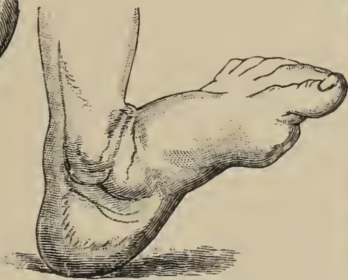


Fig. 388.—Pes calcaneus paralyticus.

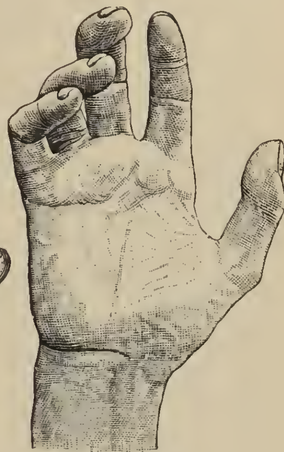


Fig. 389.—"Claw position" (main en griffe) of the fingers following paralysis of the ulnar nerve.

Infantile Spinal Paralysis.—As the spinal paralysis of children often leads to paralytic contractures, it should be briefly described at this point. The disease usually attacks children between one and four years of age. The acute infectious diseases and rheumatism have an important etiological bearing upon it, and heredity is sometimes to be taken into consideration. Pathologically it is an acute inflammatory process situated in the anterior grey horns of the spinal cord (poliomyelitis acuta), and is most commonly located in the lumbar, less often in the cervical, enlargement; it is either unilateral or bilateral, and is characterised by hyperæmia, by hæmorrhages, and by red softening with degeneration of the ganglion cells and nerve fibres. This inflammatory process, which at the outset is acute, results in the development of a circumscribed or diffuse sclerosis (connective-tissue growth) with secondary atrophy of the nerve fibres, and a subsequent secondary descending degeneration of the nerves. The muscles supplied by these nerves likewise undergo a degenerative atrophy, and in addition become the seat of a secondary interstitial growth of connective tissue or fat. The atrophy of the nerves and their roots is a secondary change, and that of the muscles is a result of the loss of their trophic centres in the anterior columns of grey matter. Leyden states that the affection may also result from a peripheral multiple neuritis, the latter in part remaining peripheral and in part leading to localised disease of the spinal cord.

I must refer the reader to the text-books on nervous diseases for a full description of the symptomatology of infantile spinal paralysis, as only the following brief outline will be given here. The disease usually begins suddenly without prodromata, with a high fever, 40° to 41° C. (104° to 105·8° F.), and corresponding acute manifestations accompanied by stupor, convulsions, etc. Occasionally this acute febrile onset is absent. After one or two days the acute manifestations generally disappear. The paralysis develops during the time that the temperature is elevated, but is usually not noticed till later. It spreads at first very rapidly, and may affect all the muscles of the limbs and even those of the trunk. It then ordinarily diminishes, leaving a permanent paralysis which varies greatly in extent, but is generally monoplegic and confined to one leg, less often paraplegic, and still more infrequently takes the form of spinal hemiplegia or of crossed spinal hemiplegia (leg and arm of different sides). Often only parts of a limb, or, more exactly, only certain groups of muscles, are affected. The permanent paralysis is purely motor, and is characterised by a rapidly progressing atrophy of the muscles. Within one or two weeks the faradic excitability is lost, though at the outset there is a temporary increased response to the galvanic current, especially to the positive pole. There are to be noted, in addition to the reaction of degeneration, the absence of the cutaneous and tendon reflexes in the region where the muscles are paralysed, the not uncommon hyperalgesia of the latter on pressure, and their steadily increasing atrophy, and, above all, the previously mentioned contractures which most frequently occur in the foot. The treatment is given on page 706.

The Manner in which Contractures Develop.—How do the various paralytic contractures which occur in such typical forms come to take place? Delpech was of the opinion that they were produced by active shortening of the non-paralysed antagonistic groups of muscles, and that for this reason the contracture took place towards the side of the antagonists. But Volkmann and Hueter have shown that this antagonistic theory is not in itself sufficient to explain the manner in which paralytic contractures develop; that, in fact, the contracture of the antagonists is quite commonly absent, and that, in addition, the contracture really forms in the direction of the paralysed group. They proved that the weight of the limb, and, in the case of the lower extremity, the superimposed weight of the body, play very important parts in the production of the paralytic contractures. This is the way in which the pes equinus paralyticus (Fig. 387) develops, since the foot drops down of its own weight—in other words, assumes a position in plantar flexion, no matter whether all the muscles of the leg below the knee or

only the extensors are paralysed. This equinus position of the foot may also result from a paralysis which is limited to the muscles of the calf alone, for the reason that the paralysed muscles undergo a shortening from lack of nutrition. The weight of the paralysed limb can likewise be shown to have an effect upon the development of contractures in other joints of the upper and lower extremity.

The pressure exerted upon the paralysed part by the weight of the body is a matter of importance in the production of the various contractures which may occur in the spinal column and in the lower extremity when the affected limb is used for standing and walking. This partially explains the way in which the paralytic scoliosis and paralytic flat-foot develop. The rare deformity known as pes calcaneus (Fig. 388), which is usually combined with a valgus position—i. e., a dropping of the inner border of the foot—is, according to Volkmann, caused by a tipping forward of the os calcis, due to the latter not being held firmly enough in position by the muscles of the calf.

The diagnosis of paralytic contractures is usually easy, and can be made from their general appearance, without an electrical examination (see Injuries of Nerves, Diseases of Nerves, § 87, § 88, and § 97).

The pure myopathic contractures due to primary disease of muscles are much rarer than the neuropathic, and result from certain forms of atrophy, injury, and inflammation of muscle (see § 98).

The cicatricial contractures, especially those due to loss of substance in the skin and subcutaneous soft parts following acute and chronic inflammations of the soft parts and joints, have already been sufficiently described in the chapters on Healing of Wounds (§ 61) and on injuries and Inflammations of the Soft Parts (§§ 87–100).

We have thus gained an understanding of the numerous causes which give rise to contractures, and can now distinguish two main groups of those which involve joints, basing the classification upon the manner in which they originate. These are, (1) *arthrogenic* contractures resulting from congenital or acquired changes in the parts which constitute the joint, and (2) *non-arthrogenic* contractures due to pathological changes in the neighbourhood of the joint, or to other diseases, especially those of the nervous system. The neurogenic, myogenic, and tendogenic contractures which follow diseases or injuries of the nerves, muscles, or tendons, or are brought about by shrinkage of fascia, etc., belong to the non-arthrogenic class. The cicatricial contractures which follow losses of substance from traumatism or inflammation, or are the result of adhesions, may occur in any part of the body. Contractures of joints are sometimes produced by causes which are partly arthrogenic and partly non-arthrogenic, as, for example, in

chronic inflammations of the hip (coxitis), where there develops along with the inflammation a progressive shrinkage of the fascia lata, unless this is prevented by proper treatment (Fig. 390). Muscular contrac-

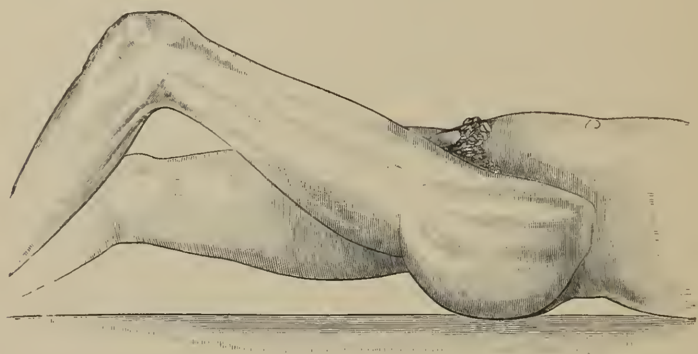


Fig. 390.—Contracture of the hip-joint in coxitis from shrinkage of the fascia lata.

tures in diseases of joints are also very frequently caused by reflex action, as described on pages 549 and 554.

Treatment of Deformities and Contractures of Joints.—The treatment of very many of the deformities and contractures of joints belongs really to the province of orthopædic surgery, which has made great progress in the last few years. It would require too much space to describe at length the treatment of each separate deformity, but it will suffice to say here that in general the treatment consists in the use of immobilising dressings (plaster of Paris, extension), supporting apparatus, operative measures (osteotomy, tenotomy, myotomy), electricity, massage, and gymnastics. The treatment of cicatricial contractures which have resulted from inflammation and injury of the soft parts has already been spoken of in connection with Injuries and Inflammations of the Soft Parts (§§ 87–100), and the treatment of arthrogenic contractures has been given in connection with inflammations and anchylosis of joints (§§ 113–118).

The treatment of infantile spinal paralysis consists in the use of massage, electricity, and a strengthening mode of life. A weak constant current should be applied to the spinal cord as early as possible, by placing one of the large, flat electrodes over the portion which is supposed to be the seat of the disease, and the other electrode on the anterior surface of the trunk, and then alternating the action of the anode with that of the cathode. In addition, the muscles themselves are treated with weak faradic or constant currents, and massaged, or rubbed with alcohol. Baths (hot baths, salt baths, sea baths, etc.) are

useful, as well as other hydrotherapeutic measures; also the internal administration of the iodide of potassium, nitrate of silver, ergotine, iron, strychnine, cod-liver oil, and finally good air and nourishing food. Supporting apparatus or immobilising dressings should be used to prevent the occurrence of deformities, especially in the lower extremities.

The congenital spastic contractures are treated at first by passive movements of the joints, and later by lukewarm baths, galvanisation of the spinal cord, and irritation of the skin along the spinal column. In order to prevent or correct deformities, it is a good plan to use plaster-of-Paris dressings or suitable orthopædic contrivances. Tenotomy is often of great value; it not only corrects deformity, but acts directly as an antispasmodic measure.

§ 120. **Injuries of Joints.**—Injuries of joints are divisible into two main groups, (1) subcutaneous and (2) open. The latter are also called penetrating, as they enter the joint-cavity. We shall first take up contusions of joints.

Joint Contusions.—Contusions resulting from a blow with some blunt instrument, or from a fall, are the mildest form of injury to a joint. The contusions may be direct or indirect, depending upon whether the violence which causes the injury acts directly upon the joint, or indirectly by *contre coup.* Indirect contusions of the hip, for example, are caused by a fall upon the feet or upon the trochanter. In indirect contusions the principal injury is a greater or less amount of crushing of the articular surfaces brought about by the latter being forced against one another, and in the worst cases a fracture may occur with impaction of the fragments; but in direct contusions it is mainly the surrounding soft parts and the synovial membrane which are injured.

The most important symptom of a contusion of a joint is the effusion of blood into the latter—the hæmarthros—which is in some cases slight, in others very marked, so that the joint feels tense. If the joint is filled to its utmost limits it becomes slightly flexed, as this position renders it most relaxed and gives it its greatest capacity. The effusion of blood is, of course, most easily made out in joints like the knee, which are superficially situated. In hæmophilia and scurvy an effusion sometimes occurs spontaneously, or as a result of very slight injuries. Other symptoms of joint contusions are an infiltration of the skin and the subcutaneous soft parts with blood, especially if the contusion is direct; pain in the joint, which is usually slight, and made worse by movement; and disturbance of function, varying with the amount of blood which is effused. For the symptoms caused by a fracture of the bony parts of a joint the reader is referred to § 101 (Fractures).

The subsequent course of a contusion of a joint which is not complicated by a fracture is, as a rule, favourable, and complete recovery usually follows in a short time, though occasionally slight inflammatory symptoms, or hydarthros, persist for a good while. It is only in very exceptional instances that suppuration takes place within the joint, from a suppurative process which originates in a laceration of the skin, gradually extends to the deeper parts and finally involves the articulation. Suppuration of the effusion of blood, due to micro-organisms which are deposited by the circulating blood, is extremely rare, but in a tubercular or scrofulous person a tubercular inflammation not infrequently results from a contusion or sprain of a joint.

The diagnosis of contusion can usually be easily made from the swelling of the joint coming on after a traumatism, from the fluctuation, the pain on movement, and the more or less marked loss of function. The effusion, if sufficient in amount, assumes the outward configuration of the joint. The possibility of hæmophilia, as well as of fracture, should always be thought of, and as careful an examination as possible made with these in view.

The treatment of joint contusions consists in the employment of massage at an early period, in order to get rid of the effusion by pressing it into the interstices between the tissues and by causing it to be absorbed by the lymphatics. Pressure applied to the joint by means of elastic bandages, and, above all, repeated movements of the joint, also promote the resorption of the blood. In this way joint contusions are made to get well very rapidly, and even very large effusions will disappear in a few days if massage is begun as soon as possible after the accident. Contusions of joints used to be treated by keeping the joint at rest and by applying ice. Ice is seldom necessary, and then only in the first stages, to soothe the pain; but keeping the joint at rest is actually harmful in typical cases uncomplicated by a fracture, as the organisation of the effusion into connective tissue is thus materially helped. Puncture and antiseptic irrigation of the joint (see page 665) are only necessary when the joint is distended to its utmost capacity. For the treatment of a hydarthros or suppuration of a joint which may follow a contusion, the reader is referred to §§ 113, 114. A subcutaneous fracture within a joint is treated according to the rules laid down on page 596.

§ 121. **Sprains** (*Distortions*).—By a sprain or distortion we mean a momentary, forcible stretching and twisting of a joint, usually combined with a laceration of certain portions of its capsule and ligaments. At present we shall omit all mention of the severe, complicated lacerations which are accompanied by opening of the interior of the joint, as we

shall return to these injuries under the subject of Penetrating Wounds of Joints, and shall confine ourselves here simply to a description of the typical subcutaneous sprains or distortions which occur with such great frequency.

Besides the stretching and tearing of the capsule and ligaments of the joint and the periarticular soft parts which we have just mentioned, there also occurs a temporary change in the normal position of the articular ends of the bones—a momentary partial dislocation, as it were—but as soon as the force has ceased to act they return to their proper position. Sprains are usually caused by the same sort of violence as dislocations (see § 122)—i. e., by forced movements which are carried beyond the physiological limits, or which are at variance with the normal mechanism of the joint. The amount of force applied in causing sprains is, however, not sufficient to bring about a more than temporary separation of the articular ends of the bones, and only a stretching or partial tearing of the capsule and ligaments takes place, though in the severest cases these structures may be completely ruptured. Sprains of the wrist are usually the result of hyperextension, hyperflexion, or torsion of the hand, and those of the ankle of forced pronation or supination of the foot. Simultaneously with sprains of the joint the neighbouring muscles and tendons are of course often stretched and lacerated, but a partial or complete rupture of the muscles and tendons or dislocation of the latter is only observed in rare instances. Injuries of bones, consisting in contusions of their articular ends, or in tearing or chipping off portions of them, are common occurrences in distortions. Examples of such injuries are fractures of the fibula or internal malleolus in sprains of the ankle, fractures of the lower end of the radius in sprains of the wrist, and cortical tear-fractures (*Riss-fracturen*)—i. e., the tearing away of pieces of bone which form the points of insertion of ligaments and tendons. I should not omit mentioning the dislocations of interarticular cartilages which may take place—the semilunar fibro-cartilages of the knee, for example—in sprains of the latter joint.

The symptoms of a sprain consist mostly in a very intense pain, in consequence of which the active function of the joint is disturbed, the joint becoming completely powerless and as though paralysed. There is usually a diffuse swelling of the joint, caused by the intra-articular and periarticular effusion of blood, and if a fracture is present at the same time this effusion is very marked. Later, owing to changes in the colouring matter of the blood situated in the skin and subcutaneous tissue, bluish-red, bluish-green, dark yellow or yellow discolourations make their appearance. The subsequent course of sprains in typical

cases is usually favourable, and as a rule, if proper treatment is adopted, they get well very rapidly. In cases complicated with a fracture, the final outcome, especially as regards restoration of the function of the joint, is dependent upon the nature and location of the break in the bone. Complicated cases of sprain may occasionally give rise to chronic deforming inflammations of the joint, which obstinately resist every form of treatment. In other instances anchylosis may develop, or the opposite conditions may be encountered, the articulation becoming loose and flail-like from the stretching and displacement of its various constituents, so that subluxations, or partial dislocations of joints, like the wrist, knee (genu valgum), or ankle (flat-foot), may result. The consequences which may ensue from an unrecognised rupture of a tendon or separation of the latter from its point of attachment are also worthy of consideration. Sprains, like contusions, are only followed by acute suppuration of the joint in very exceptional instances; but not infrequently predisposed individuals may subsequently acquire a tubercular arthritis in a joint which has been the seat of a distortion.

The *diagnosis* of sprains can be easily made from what has been said; but the joint should always be carefully examined for fracture, especially when the injury is near the hand or foot.

The *treatment* of subcutaneous sprains which are not complicated by a fracture is essentially the same as that of a contusion of a joint, and consists in early massage, intermittent bandaging of the joint with an elastic bandage, and the use of methodical movements. Antiphlogesis is very frequently not necessary, or at most only in the first few hours or days. Massage, in cases not complicated by a fracture, frequently seems to act in a marvellous way, and a joint which is still perfectly stiff and without function may again be made capable of active motion and of performing all its functions by massaging it only once. The sooner massage is begun the better. Rest and immobilisation in uncomplicated cases are to be condemned. If a fracture is present, it should of course be treated according to the general principles which apply to it. In the rare cases of complete rupture of the tendons or capsule, the joint must likewise at first be immobilised until the tears in these structures have united. If tendons have been ruptured, their ends may ultimately have to be joined together by catgut sutures. Other complications, such as suppurative arthritis—which very rarely occurs—are to be treated in the usual way. Puncture and antiseptic irrigation of the joint, on account of extreme distention of the latter with blood, are called for only in exceptional instances.

§ 122. **Dislocations (Luxations) of Joints.**—By a dislocation is meant

a permanent displacement of the articular ends of two or more of the bones making up the joint. Dislocations are complete or incomplete, the latter also being called subluxations. In *complete* dislocations the opposed joint surfaces are entirely separated from one another, while in the *incomplete* variety the articular ends are still in contact, having merely changed their relative positions in regard to each other. The dislocations of amphiarthroses like the symphysis pubis are usually called diastases. A distinction is also made between recent and old, and between simple and complicated or compound dislocations. The latter include those especially which are associated with open wounds in the soft parts, with ruptures of large vessels or nerves, or with fractures.

As regards the causation of dislocations, we distinguish (1) the traumatic, due to external violence, (2) the spontaneous, pathological, or inflammatory dislocations which occur in the course of an inflammation in a joint, and (3) the congenital dislocations.

I. **Traumatic Dislocations.**—Traumatic dislocations are almost always the result of external violence, rarely of excessive muscular action. The force is usually applied indirectly, so that the bones are separated from one another by leverage, the power being exerted at a greater or less distance from the joint. Thus, as a rule, forced movements are caused to take place which go beyond the physiological limits of flexion, extension, abduction, adduction, pronation, or supination, or movements are produced which are at variance with the normal mechanism of the joint, particularly forced rotation. In every joint there exists a mechanism for checking its motion; this is generally made up of bone, less often of the ligaments or capsule of the articulation. When a dislocation takes place this natural inhibitory mechanism is overcome, and the articular end of the bone is pressed against this check to its further movement, which then becomes the fulcrum. If the force ceases to act at this stage, the articular ends of the bones return to their normal position of contact with one another, and only a sprain is the result; but if the force keeps on acting, one of the articular surfaces is lifted from the other, the capsule ruptures, the ligaments and muscular insertions which resist are stretched or likewise ruptured, and the articular end of the bone escapes either partially or completely from the capsule.

In a dislocation of the elbow from over-extension, the olecranon fossa acts as the fulcrum against which presses the tip of the olecranon process. At the hip the rim of the acetabulum is the fulcrum. The point where the displaced articular end of the bone finally comes to rest depends upon the nature of the movement and the amount of force brought to bear. After the force which produces the injury has

ceased to act, the dislocated articular end of the bone is made to assume some particular position by a so-called *secondary movement*, brought about by the elasticity of the soft parts—skin, ligaments, capsule, and muscles. In this the weight of the limb and the movements made by the injured person or by others are also to be taken into consideration. The dislocated articular end of the bone is held in its new position mainly by means of the uninjured portions of the capsule and accessory ligaments. The dislocations caused by direct violence, such as a blow or fall upon the joint, are much rarer.

Occasionally dislocations result from muscular action, especially at the shoulder (Cooper, Streubel, etc.), where they have been caused by making attempts to seize an object placed above the head, or by pulling with the hand elevated. The dislocations of the lower jaw due to opening the mouth too wide, as in yawning, are also produced by muscular action; and dislocations following general muscular contractions, as in epilepsy or eclampsia, belong to the same category.

Many persons can dislocate their joints voluntarily; but these dislocations—that of the first phalanx of the thumb being a common example—are not ordinarily complete, though in some instances they may be. The well-known athlete Warren was able at will to completely dislocate most of his joints, including the shoulder and hip, and, in the case of the latter, to cause the head of the femur to lie two inches above Nélaton's line. Then, when he wished, he could reduce it again, causing a loud, snapping sound. Acrobats and so-called "snake men" bring about by constant practice such a lengthening and loosening of the capsule and ligaments of their joints that they can finally dislocate the latter and bring them back into place again voluntarily.

Occurrence of Traumatic Dislocations.—Dislocations are most common in middle life, but are very rare in old people and young children, for the reason that external violence is more likely to cause their bones to break. Young children are very apt to sustain separations of the epiphyses owing to the slight powers of resistance which the latter possess. Dislocations of the upper extremity are the most common, amounting, according to Krönlein, to 92·3 per cent. of all luxations, while dislocations of the lower extremity amount to only 5 per cent., and those of the trunk to only 2·8 per cent. Dislocation of the shoulder, on account of the freedom of motion in this joint, are the most common, constituting about one half of all the dislocations which are encountered (51·7 per cent., Krönlein). Dislocations occur from three to five times more frequently in men than in women, because the former are more exposed to injuries on account of their occupations. Dislocations of the lower jaw are, however, according to Krönlein, about four times more common in women than they are in men.

The anatomical changes—i. e., the amount of injury to the tissues—depend in general upon the nature and intensity of the force which is brought to bear and the anatomical structure of the joint in question. As a rule, however, the following injuries to the tissues are more or less constant: The rent in the capsule, which is always present in a complete traumatic dislocation, is sometimes slit-shaped and sometimes irregular in form; not infrequently the capsule is torn from its insertion, and may or may not carry with it at the same time a portion of the bone to which it is attached. The accessory ligaments are either stretched, lacerated, completely ruptured, or torn from their point of insertion on the bone. Similar changes take place in the muscles. The intra-articular and periarticular effusion of blood is usually not very large, and when it is, a fracture may be suspected. The most important complications of traumatic dislocations are extensive injury to the skin and subcutaneous soft parts, the simultaneous presence of a fracture, and injuries to large vessels, nerves, and internal organs.

Fig. 391.—Luxatio femoris supracotyloidea inveterata with a very perfectly formed new acetabulum (preparation from the collection in the surgical clinic at Bonn—Krönlein).

In the majority of cases of uncomplicated dislocations, after reduction of the displaced articular surfaces has been accomplished, a complete *restitutio ad integrum* usually follows, the rent in the capsule appearing to heal with especial rapidity. But if the dislocated articular end of the bone remains in its abnormal position a new more or less perfect joint is formed—a so-called nearthrosis (see Figs. 391, 380). These nearthroses are sometimes very perfectly developed, especially at the hip and shoulder. As illustrated in Fig. 391, a new socket is formed at the hip by growth of the periosteum, which becomes covered with hyaline or fibrous cartilage. The capsule is constructed by an inflammatory new formation of tissue in the surrounding soft parts, and its inner surface is gradually made smooth by the movements of the head of the bone, so that it may finally come to resemble a synovial membrane. The dislocated end of the bone usually

atrophies somewhat, and changes take place in its articular surface corresponding to the new conditions of friction; these changes are sometimes similar to those of arthritis deformans.

Symptoms and Diagnosis of Uncomplicated Traumatic Dislocations.—The symptoms of traumatic dislocations are partly objective and partly subjective. The objective symptoms are: (1) A change in the contour of the joint; (2) a change in the relative positions of the articular ends of the bones; (3) a change in the axis of the bone or limb thought to be dislocated; (4) a lengthening or shortening of the dislocated limb (Figs. 392, 393). The change in the contour of the joint is often evident to an experienced eye at the first glance. The patient should always be sufficiently undressed to render a comparison between the sound and damaged side possible; one can then note the normal configuration of the uninjured joint, the normal position of the bony prominences, the relationship of the folds of the skin and soft parts on the healthy and the abnormal depressions and elevations on the diseased side resulting from the changed situation of the head of the dislocated bone. The most important symptom—viz., the abnormal position of the head of the dislocated bone—can be recognised by palpation or by making movements with the dislocated limb.

FIG. 392.—Luxatio humeri subcoracoidea sinistra.

The altered direction in which the latter points is usually such that the long axis of the luxated bone does not strike the articular cavity of the other, but passes outside of it; in the case of the shoulder, for example, the long axis of the humerus passes outside of the glenoid cavity (Figs. 392, 393). The dislocated limb, in the majority of instances, is shortened, rarely lengthened, and assumes a position which is perfectly characteristic in every dislocation.

The subjective symptoms are pain, and inability to perform normal movements with the injured limb. The disturbances of function usually consist of a loss of active motion, while passive movements are possible to some extent. The latter are often very easily carried out in a certain direction, while in others they may be quite impossible.

From what we have just said, it follows that the diagnosis of dislocations, especially soon after the accident, is usually not difficult. If the swelling due to the effusion of blood is very large, it can be reduced in size by gentle massage, possibly under an anæsthetic. Dislocations are most likely to be confused with fractures of the articular ends of the bones. The latter may be suspected if the dislocation, or, rather, the deformity, is easily reduced by slight traction applied to the injured limb, but returns again immediately when extension is discontinued. In dislocations, on the other hand, special manœuvres are necessary to cause a disappearance of the deformity, and when reduction has once taken place the change of contour does not again recur spontaneously. In fractures, abnormal mobility and crepitus are usually present, while in dislocations there is an abnormal fixation of the limb, and certain movements are quite impossible. A kind of crepitus is also some times met with in dislocations, but it is softer than bone crepitus, and is due to blood coagula and to the tearing of the ligaments of the capsule or of the tendons.

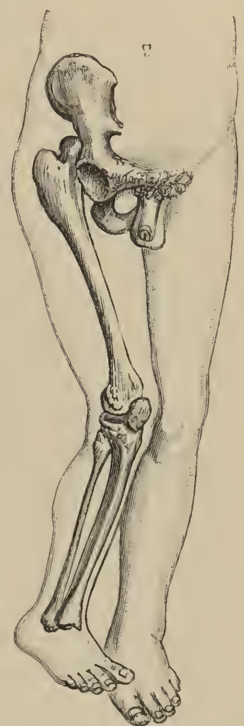


Fig. 393.—Dislocation of the hip backwards (luxatio iliaca).

Complications of Dislocations.—The most important complications of dislocations are: (1) Extensive injury to the skin and subcutaneous soft parts over the joint; (2) fracture occurring simultaneously with the dislocation; (3) rupture of large vessels and nerves; (4) injury to internal organs.

Division of the skin and subcutaneous soft parts with exposure of the head of the dislocated bone is not common; it is observed most often at the elbow, in the fingers, at the knee, and at the ankle. Such compound dislocations are always to be looked upon as serious injuries, especially when they are combined at the same time with fracture. The sooner a compound dislocation is subjected to antiseptic treatment the better will be the prospect of preventing infection and a serious suppurative arthritis (see § 123, Wounds of Joints).

The most common complication of a dislocation is a fracture occurring at the same time. The fracture may either involve the cortex, a portion of bone being torn off at the point of attachment of some ligament or tendon, or the fulcrum, or the dislocated bone itself, or the

non-dislocated parallel bone, such as the ulna, which may be broken below the elbow in forward dislocations of the head of the radius. The fractures of least importance are those of the cortex and of bony prominences like the tuberosities of the humerus or the malleoli. Fractures of the rim of the acetabulum at the hip, and of the glenoid cavity at the shoulder, are, on the other hand, more serious, since they increase the difficulty of reduction or favour a recurrence of the dislocation. If a fracture occurs in a dislocated bone, the dislocation usually takes place first and then the fracture.

Rupture of large vessels or nerves is very rare, and is sometimes the result of unskilful reduction of an old dislocation. Stretching and crushing of the vessels and nerves are, however, more common. Crushing of the vessels occasionally gives rise to extensive thrombosis followed by gangrene, especially if the dislocation is not promptly reduced. Of the injuries of nerves, those of the circumflex, with paralysis of the deltoid muscle, are the most frequent.

Of the injuries of internal organs, I should mention injury of the spinal cord in dislocation of the vertebræ, of the bladder, intestine, and pelvic organs in *luxatio femoris centralis*—i. e., dislocation of the femur inwards through the acetabulum, also compression of the trachea and œsophagus in dislocation of the sternal end of the clavicle, etc. Prochaska saw a case in which the head of the humerus penetrated the thorax between the second and third ribs.

Prognosis of Traumatic Dislocations.—As regards the prognosis, it is important for us to consider (1) whether we have to deal with a simple or a compound dislocation, (2) whether complications are present, and, if so, their nature, and (3) the region of the body and the particular joint where the dislocation has occurred. We usually expect perfect recovery to take place in the case of simple uncomplicated dislocations which have been successfully reduced. Should the dislocation not be reduced, a new joint or nearthrosis is formed, as we saw above, in the abnormal situation occupied by the articular end of the dislocated bone, particularly if the dislocation were one of the shoulder or hip. Occasionally a dislocation will recur from even a very slight amount of violence, and particularly if extensive movements are made with the joint at too early a period.

We sometimes meet with individuals who in this way suffer from very frequent recurrences of the same dislocation, especially that of the shoulder, jaw, or the hip, and there are people who have dislocated their shoulder or jaw more than fifty or one hundred times. These "habitual dislocations," as they are called, have many different causes, but they are usually due to a lax condition of the capsule and its accessory liga-

ments, which have become stretched and torn to such an extent that the cavity of the joint is enlarged, and a dislocation can take place without the occurrence of any fresh laceration.

Treatment of Traumatic Dislocations.—The treatment of recent uncomplicated dislocations consists in bringing the displaced articular end of the bone back into its socket by special methods of reposition, and then immobilising the joint until the rent in the capsule has healed. The reposition was at one time carried out in a very forcible and rough way, and not infrequently with the aid of mechanical contrivances, pulleys, etc.; so that sometimes disastrous consequences—such as severe injuries to the skin, vessels, nerves, and muscles, or fractures—followed, and in some instances even entire extremities were torn away. At present we have in chloroform anæsthesia an excellent means of rendering the reduction of dislocations easy and painless. An attempt should first be made to reduce a recent dislocation without an anæsthetic, and if this is found to be impossible chloroform should be administered, but with great caution, because a collapse resulting in death may easily take place, especially in habitual drinkers, who are much excited by the accident. The sooner after the accident reduction is performed the more easily it is accomplished. The movements employed for reducing a dislocation must be carried out according to certain rules, which vary with the nature of the case, and in making them one should always take into consideration the shape of the joint and the nature and location of the rent in the capsule. *Impediments* to the reduction of recent dislocations are furnished by active contraction of the muscles, by the narrowness or unfavourable location of the rent in the capsule, by portions of capsule which still remain intact though stretched and abnormally situated, and by interposition of portions of the capsule, tendons, muscles, and fragments of bone. Active contraction of the muscles and the elastic tension of the soft parts are overcome by chloroform anæsthesia. It is evident that the movements made in accomplishing reduction must differ very greatly according to the nature of the case and the site of the dislocation; that sometimes rotation, sometimes flexion or extension, and sometimes abduction or adduction must be performed; and Krönlein is right in saying that it is not so much the etiology of a dislocation as it is its anatomy which determines our method of treatment. By means of the movements or manipulations aimed at reduction the head of the dislocated bone is brought opposite the rent in the capsule or the socket, and then, with a snapping sound or perceptible jolt, caused to enter the cavity of the joint. As a rule, it is well to combine with the above-mentioned manipulations a direct pressure upon the articular end of the dislocated

bone. For the methods of reducing the various dislocations of the different joints I must refer the reader to my Special Surgery. The restoration of the normal contour and functions of the joint will show at once that the reduction of the dislocation has been successful.

The after-treatment consists in keeping the replaced portions of the articulation at rest by means of light, immobilising dressings. In dislocations of the shoulder, for example, it will suffice if the arm is held firmly fixed by a mitella (see Fig. 155), which is secured in position by a few turns of a bandage around the arm and thorax. In dislocations of the hip the patient should be kept in bed, a spica coxæ (see Fig. 143) applied about the joint, and the limb immobilised by a cloth passed around the leg in the region of the knee. It is difficult to keep some joints reduced, as is the case with forward dislocations of the head of the radius and dislocations of the acromio-clavicular and sterno-clavicular articulations. In such instances an attempt must be made to hold the bone in place by dressings which exert pressure, by pads, or, when necessary, by the use of nails or bone sutures. After the lapse of some eight, ten, or fourteen days—depending upon the nature of the case—passive motion of the dislocated joint should be begun in order to prevent subsequent stiffness. Forced movements of the joint should, however, not be attempted during the next few weeks, because the healing of the lacerations in the capsule and ligaments may be interfered with, or the cicatrices of these structures may be so stretched that the dislocation easily recurs, or even becomes habitual.

The treatment of habitual dislocations, as a rule, is very difficult, particularly in marked cases. Long-continued rest of the joint in one position is usually unsuccessful, because the injured person has not the required patience. Very often nothing remains but to restrict the movements of the joint by means of a suitable bandage. In bad cases it may be well to expose the joint under antiseptic precautions, and either suture the rent in the capsule or resect the head of the bone. Genzmer successfully treated two cases of habitual dislocation—one of the shoulder and the other of the jaw—by the subcutaneous injection of pure tincture of iodine (0·5 to 0·75 cubic centimetres tinct. iodi injected by a hypodermic syringe at intervals of three to four days, until six to eight injections have been made). Subcutaneous injections of absolute alcohol might also be tried.

In fresh dislocations which are irreducible an aseptic arthrotomy should be performed—i. e., the site of the dislocation should be exposed by an incision and the head of the bone then brought back into place, or resected if reduction is otherwise impossible. But recent

simple dislocations seldom require operative interference, since reduction can generally be accomplished, especially if chloroform is used.

One should first try to reduce even old dislocations by the usual method, though they may have existed for weeks, months, or years; luxations of the shoulder and also of the hip have thus been successfully brought back into place two years after the accident. The possibility of reduction in these cases depends mainly upon the extent of the injuries which the soft parts have suffered, upon the greater or less degree of fixation of the dislocated articular end of the bone in its new position, and, finally, upon whether the joint cavity is much diminished in size or quite obliterated. After thoroughly anæsthetising the patient with chloroform, the same manipulations are employed for the reduction of old dislocations as for those which are recent, the articular end of the bone being first freed by rotatory movements. The manipulations aimed at reduction should be made with great care so as not to injure the bones or soft parts. The mechanical contrivances once so extensively used, such as pulleys, windlasses, etc., have become obsolete and have only a historic interest. Even though the reduction is successfully accomplished a good result is not always assured, as the joint often remains stiff in spite of massage, electricity, and active and passive motion. If reduction is impossible, the dislocation should be exposed by an incision—i. e., arthrotomy should be performed and the head of the bone returned to its normal position, especially in those cases in which the limb has become useless owing to malposition, or in which the dislocated articular end of the bone causes pain and paralysis by pressing upon the nerves. In such instances resection of the articular end of the bone will often be necessary as a preliminary step in performing reduction. At the hip the position of the limb is sometimes best corrected by osteoclasis or subtrochanteric osteotomy. In other cases of old irreducible dislocations one may try to make as good a nearthrosis as possible by means of massage, passive motion, electricity, and warm baths.

Dislocations in which there is an opening at the same time into the joint are treated by the same rules that apply to wounds of joints (see page 723). Under these circumstances, also, reduction should be performed as promptly as possible, taking every antiseptic precaution and providing for drainage of the joint. According to Drewitz, reduction without resection of the head of the bone gave, even in preantiseptic times, movable joints in forty per cent. of the cases. If difficulties are met with in performing reduction the knife should be made use of, and when reduction has been accomplished the joint should be carefully drained and immobilised. If the soft parts have been very much

injured permanent irrigation should be employed. Resection of the head of the dislocated bone is indicated in cases complicated by comminuted fractures, extensive injury to the soft parts, suppuration within the joint, or where reduction is impossible by other means. If sepsis has already made its appearance prompt amputation or disarticulation may be necessary.

If both dislocation and fracture occur together, it should be our first aim to reduce the dislocation when this is possible, using, for example, direct pressure upon the articular fragment in the case of dislocation and fracture of the humerus at the shoulder joint. In other instances reduction of the dislocation may be impossible, and the fracture must first be allowed to heal before the dislocation is attended to. In suitable cases operative measures must be undertaken—i. e., the seat of injury should be exposed, and whatever measures the condition calls for adopted. The prognosis of all dislocations which are complicated by fracture should be looked upon as doubtful as regards restoration of the normal mobility of the joint.

The other complications, such as injuries to vessels and nerves, are to be treated in the usual way (see § 88).

Dislocation of the semilunar cartilages of the knee rarely occurs independently of other changes in the joint. Habitual dislocation of these cartilages has been observed, the most common variety being a displacement of the inner cartilage forwards, due to forced flexion of the knee joint combined with outward rotation of the foot, or, rather, leg. The displaced cartilage can be felt on the anterior border of the joint, the knee is somewhat flexed, and complete extension is impossible.

For a description of dislocations of tendons and nerves see pages 509, 510.

II. **Pathological or Spontaneous Dislocations** are observed in the course of diseases of joints either as a result of an abnormal stretching or lax condition of the capsule and ligaments, or of changes within the joint such as those caused by arthritis deformans or caries. Under such circumstances either an incomplete or a complete dislocation takes place, coming on gradually and brought about by the weight of the limb, or suddenly from some slight traumatism, muscular action, etc.

We distinguish: 1. *Distention Dislocations*, due to a stretching or lax condition of the capsule and ligaments of the joint caused by a serous, sero-fibrinous, or more rarely suppurative effusion. Complete and incomplete dislocations of this kind are especially common in the course of metastatic inflammations of joints with large collections of fluid, such as occur in typhoid fever, small-pox, measles, scarlet fever, diphtheria, puerperal fever, and pyæmia. The capsule and ligaments of a joint—the shoulder, for example—may also become

stretched in cases of muscular atrophy and paralysis. Under these conditions the muscles are not capable of supporting the extremity, and thus allow displacements of the joint surfaces to take place either gradually or suddenly. The voluntary dislocations mentioned on page 712 are likewise looked upon by some authors as distention dislocations.

Quite recently Verneuil has called attention to dislocations which occur during acute articular rheumatism and run a course exactly like that of traumatic dislocations. In all cases the luxations took place suddenly and spontaneously, and could be reduced very easily under an anæsthetic. Verneuil thinks that these dislocations are caused by muscular action and a lax condition of the ligaments.

2. *Destruction Dislocations.*—The most common form of pathological dislocation is due to a carious destruction of the joint surfaces combined with corresponding changes in the capsule and ligaments. In this category belong the so-called "wandering of the acetabulum" in coxitis (page 674, Fig. 374) and the spondylolisthesis—i. e., the slipping down of the last lumbar vertebra into the pelvis in cases of tubercular destruction of the corresponding intervertebral ligaments (see § 114).

3. *Deformity Dislocations*, which are the result of changes in the shape of the bony parts of the joint due to an atrophy of bone without suppuration and without the production of granulations. They most commonly occur in connection with arthritis deformans (see page 686, Fig. 380).

For the course, diagnosis, and treatment of pathological dislocations see § 113, § 114, § 119 (Inflammations and Deformities of Joints), and the above description of traumatic dislocations.

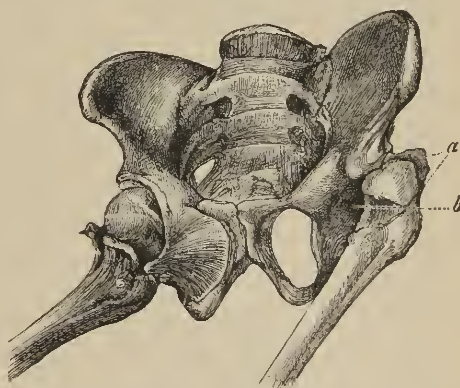


FIG. 394.—Congenital dislocation of the left hip in a six-months-old girl: *a*, remains of the capsule which has been dissected away; *b*, undeveloped acetabulum.

III. **Congenital Dislocations.** — Congenital dislocations are mainly the result of anomalous or arrested fœtal development. They are most common at the hip (Fig. 394), being very rarely found in the rest of the joints, and are occasionally combined with other anomalies of development, such as club-foot, spina bifida, and ectropion vesicæ. These congenital dislocations, which take place *in utero*, should not be confused with the traumatic ones which take place during delivery and are due to extrac-

tion of the child. This latter form of dislocation is, however, extremely rare, fractures, especially at the epiphysis, on account of the latter's slight power of resistance, being much more common.

Investigations relating to the Pathology and Etiology of Congenital Dislocations.—These investigations have to do almost exclusively with congenital dislocations of the hip. I had an opportunity at one time of examining a dislocation of this kind in a female child six months old (Fig. 394). I found that the acetabulum was very imperfectly developed, that the neck of the femur formed an obtuse angle with the shaft, and that the ligamentum teres was so much thickened and lengthened that the head of the femur, which was situated near the anterior superior spine, did not have sufficient room in the shallow acetabulum. The pelvis was, moreover, asymmetrical, but the capsule of the joint was normal.

The congenital dislocation of the hip usually belongs to the iliac variety, the head being in contact with the ilium. Lordosis of the vertebral column is present, especially in bilateral dislocations, and the patients have a very characteristic gait, like that of a duck.

Fig. 395.—The manner in which a congenital dislocation of the hip is produced: the leg of the fœtus is forced to assume an abnormally adducted position by a uterus which is too small (W. Roser).

The main cause of congenital dislocation of the hip is probably to be found in an imperfect development of the acetabulum or the cotyloid ligament, and its occurrence is favoured by extreme flexion and adduction of the thighs of the fœtus (Fig. 395, Dupuytren, Roser). A very small uterus, which exerts abnormal pressure upon the fœtus, thus causing the latter to assume a cramped position, may possibly have a deleterious influence upon the development of the hip joint. The obtuse angle which the neck of the femur makes with the shaft (Fig. 394) should also be noted, as this is probably not always a secondary condition, but one which may sometimes develop primarily from the above-mentioned cramped position of the fœtus brought about by a uterus which is deficient in size. Owing to the obtuse angle which the neck of the femur forms with the shaft (Fig. 394), the head, as it were, grows past the acetabulum instead of into it. Other cases of congenital dislocation are probably the result of an abnormally long and thick ligamentum teres, which, as in the case I examined, does not give the head sufficient room in the acetabulum. Another important fact, from an etiological point of view, is that congenital dislocations of the hip are much more common in females than in males, 87·6 per cent. of all cases occurring in the former sex.

From careful examinations which I have made of the fœtal pelvis, I believe that this latter fact can be explained by the comparatively vertical position of the ilium in females, which, in conjunction with the abnormal angle formed by the neck of the femur with the shaft, readily allows the head to leave the shallow acetabulum and glide up on to the ilium.

It follows from what has been said that the congenital dislocations of the hip are undoubtedly to be ascribed to anomalies in the development of the fœtus due to various causes.

The rare cases of congenital dislocations of other joints of the body are probably also due to fœtal anomalies of development. Congenital subcoracoid, subacromial, and infraspinous dislocations of the shoulder have been reported, as well as congenital dislocations of the elbow, wrist, knee, and ankle. At the elbow, congenital dislocation of the head of the radius—backward, outward, forward, or inward—is the most common.

The symptoms, diagnosis, and treatment of congenital dislocations of the different joints are taken up at length in the Special Surgery, and I will only briefly state here that the prognosis is usually unfavourable, although fairly good results have been obtained in dislocations at the knee. Effective treatment is generally very difficult, as the dislocations are ordinarily not recognised until too late. Patients do not, as a rule, come under observation until the joint has undergone such changes that a reduction is no longer possible. Little or no benefit results from immobilisation carried out for a long time, or from extension or supporting apparatus. Recently König and others have tried to expose the head of the femur in cases of congenital dislocation of the hip by Langenbeck's incision, and then to free the head sufficiently by subperiosteal division of the muscular insertions and soft parts to enable it to be drawn down into the region of the acetabulum. If there is no acetabulum, or if, as is usual, it is only rudimentary, it must be chiselled out, or an artificial one made by means of a flap of periosteum and bone. I have found it very difficult, especially in older children, to keep the head in the neighbourhood of the acetabulum, either immediately after the operation or later, when the wound has healed, on account of the obtuse angle made by the neck of the femur with the shaft. I obtained, however, an excellent result in the case of a boy three years old with a unilateral dislocation, because the

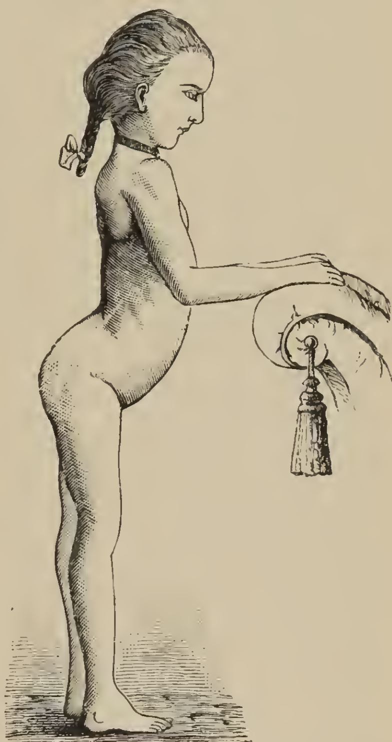


Fig. 396.—Double congenital dislocation of the hip.

acetabulum was abnormally deep, so that the head found sufficient support, even without enlarging the acetabulum artificially. This was the deepest acetabulum that I have ever seen in a congenital dislocation; and as the ligamentum teres had ruptured, I doubt if this was, after all, a true congenital dislocation. It was, more likely, a traumatic dislocation, acquired at a very early period—an injury which, as is well known, is extremely rare in the first years of life.

§ 123. **Wounds of Joints.**—Wounds of joints consist of punctured, incised, and contused wounds, and wounds which are complicated with fracture, including gunshot wounds (see § 124). Any wound which opens a joint—a so-called penetrating wound—even though extremely small, should be looked upon as a very serious injury, since it may more or less completely destroy the function of the joint, and even imperil the life of the patient. The escape of synovial fluid is a symptom which indicates beyond a doubt that the joint has been opened. The prognosis of penetrating wounds of joints is, however, much more favourable than it was before the introduction of the antiseptic method of treating wounds, and we now have no fear of opening a joint aseptically with the knife or trocar. But the conditions are entirely different in the case of accidental wounds made with an unsterilised instrument, or of gunshot wounds into which dirty pieces of clothing have perhaps entered. Under such circumstances germs of infection can readily make their way into the joint, and with great rapidity cause violent inflammation.

The course of a penetrating wound of a joint depends very largely upon whether or not germs of infection have gained access to the joint at the time of the accident, or afterwards.

We shall first discuss the cases in which everything is most favourable—i. e., in which no infection of the wound, a punctured one, for example, has taken place. The course of such a wound will then be as follows: The synovia makes its appearance at the time of the accident, but soon ceases to flow out, and the wound becomes agglutinated and heals up without causing any inflammation or disturbance of function in the joint. In other cases a mild inflammation occurs, taking the form of a synovitis serosa or serofibrinosa.

The course of an infected wound of a joint is quite different. Infection may take place at the time of the accident or later, and is then due to improper treatment or dirty probes, or to the fact that the patient pays no attention to the wound, and walks about, thus, by his movement of the parts, permitting air and infectious germs to have free access to the joint. In some cases the wound has already united, and then on the third to the fifth day manifestations of inflam-

mation suddenly make their appearance, and rapidly increase in severity. The joint is swollen, tense, and very painful, the skin is red and feels hot, and there is high fever. If the agglutinated borders of the wound are separated by a probe, or if the sutures are removed, pus immediately makes its appearance. Other cases, especially those in which there is a large effusion of blood, run a more acute course, and the local and general symptoms of suppuration in the joint come on within twenty-four hours after the injury. These are the most unfavourable ones, and unless the infected contents are promptly removed by freely opening up the joint, followed by drainage and antiseptic irrigation, or, if necessary, by resection, acute gangrene of the joint may rapidly follow, with, perhaps, constitutional sepsis.

In another group of cases the course is more subacute, and though the exudate within the joint is very large it is not noticeably suppurative in character, but looks like cloudy synovia mixed with flakes containing pus-cells (see § 113).

The final outcome of an infected wound of a joint varies, though if it receives antiseptic treatment early enough recovery is assured. In some cases, after a longer or shorter time, the suppurative inflammation gradually gets well spontaneously without any particular antiseptic treatment, but in others which are not properly attended to the suppuration becomes progressive, breaks through the capsule of the joint, and gives rise to suppuration in the neighbourhood, while the inflammation in the joint itself apparently diminishes in intensity. Such suppurative processes not infrequently run a very tedious course, gradually going on to pyæmia, to which or to extreme exhaustion the patient succumbs. The worst cases are those in which death occurs from acute septicæmia within a few days. These septic or gangrenous inflammations of joints may be caused by a very slight injury, such as puncture of the joint with a sewing needle, and they may run such a rapid course that even on the fourth or fifth day death from septicæmia cannot be prevented even by amputation or disarticulation. We have already described the course and outcome of the different varieties of acute inflammations of joints in the chapters devoted to Joint Inflammations.

The Repair of Wounds in Cartilage.—Gies has made experiments on young dogs with reference to the repair of wounds made in cartilage and has come to the conclusion that clean aseptic wounds in this tissue never heal, but remain permanently unchanged, while wounds which are made in the presence of micro-organisms heal up so completely as not to leave any or scarcely any traces behind them.

The escape of synovial fluid in all recent cases which come under observation immediately after the reception of the injury has, as we remarked before, a very important bearing upon the diagnosis of penetrating wounds of a joint. In some instances in which the joint is laid wide open the exposed articular cartilages may be recognized at the first glance. But not infrequently the puncture or other wound is already closed, so that it is doubtful whether the joint has been opened or not, and under these circumstances we must quietly wait for further developments. A warning should be given here against probing wounds too freely in the neighbourhood of a joint.

Treatment of Wounds of Joints.—Every wound of a joint, even the most trivial, should be treated with the greatest care. We shall not discuss the treatment of gunshot wounds of joints, as they will be taken up later in § 124.

Absolutely fresh cases without much effusion into the joint, and without apparent infection, are treated by disinfection of the wound and its neighbourhood. I do not, as a rule, suture such wounds, but merely dust them with iodoform, cover them with iodoform or bichloride gauze which has been moistened in a 1-to-1,000 solution of bichloride of mercury, and over this place sterilised cotton. Large wounds should be packed with iodoform or sterilised gauze. The antiseptic occlusive dressing should be as large as possible, and the joint must be carefully immobilised by splints. The time for changing the dressings depends upon the subsequent course of the injury, and very often aseptic healing takes place without changing the dressing at all. But should fever make its appearance, and the patient complain of pain, the dressing must be changed immediately. If, upon taking off the dressing, it is evident that the joint has become infected and that an acute suppurative inflammation has developed, thorough disinfection and drainage of the joint must be begun at once. The joint should be freely opened, all pockets within it disinfected with a 1-to-1,000 bichloride solution, and any blood-coagula that may be present carefully removed. Short and thick drainage tubes—preferably of glass—must be inserted in those places where they can most effectually help to carry off the discharges. In suitable cases the wound is packed with iodoform gauze or sterilised mull, and it is also of the greatest importance to secure immobilisation of the joint. The dressings must be changed often, depending upon the height of the temperature. Not infrequently one has the pleasure of seeing that this treatment is followed by excellent results, that the inflammation of the joint is averted, and that, even in cases where one could hardly have expected it, perfect mobility of the joint is regained despite the fact that suppurative arthritis has occurred.

If, in spite of disinfection and drainage of the joint, severe constitutional symptoms make their appearance, or if the suppuration that is present is very extensive, so that drainage of the joint presents great difficulties, resection is then indicated; or, if general systemic infection threatens, the focus of infection must be removed by amputation or disarticulation.

If the patient comes under treatment after suppuration has already begun, antiseptic incision and drainage, or packing of the joint with or without resection, or even amputation are indicated, depending upon the amount of suppuration and the length of time the disease has lasted. In opening up old infected cases of this kind one should not be afraid of making too many incisions into the different parts of the joint. Continuous antiseptic irrigation will often be found a most excellent aid in the subsequent treatment (see page 178). Any complications that may be encountered—fractures, for instance—are to be treated in the usual way. (See page 600, Treatment of Compound Fractures.)

Appendix.

Gunshot wounds. Military practice.

§ 124. **Gunshot Injuries.**—In connection with wounds of joints, we shall give a short description of the gunshot wounds which have already been referred to several times in speaking of injuries to the different tissues. We must, of course, confine ourselves here merely to a brief sketch, and whoever cares to become better acquainted with this extremely interesting subject should read the excellent works of Stromeyer, Pirogoff, Langenbeck, Billroth, Esmarch, etc. The literature of gunshot wounds and military surgery is very extensive. Of the older books, I should speak especially of the memoirs of Larrey, the famous army surgeon of Napoleon I, and, amongst English works, of The Principles of Military Surgery, by John Hennen.

Gunshot wounds are essentially contused and lacerated wounds, and are most commonly caused by hand firearms. The projectiles of the latter (shot-guns, revolvers, pistols) are generally cylindrical or shaped like an acorn, and are usually made of lead. The bullets used in modern weapons—i. e., those of small calibre (eight millimetres), at present employed by the European armies—are long and cylindrical, and consist of a lead core encased in steel. Owing to this steel covering the bullets have great strength and retain their shape when they strike a bone or pass through the body. The penetrating power of these bullets is, as we shall see, very extraordinary, but they are nevertheless more

humane than the lead bullets. The latter become so soft from friction as they pass through the barrel of the gun and the air that they change their shape very materially and break up into single pieces, so that a sort of explosion results. When they strike bone, for example, they become flattened out, split, shattered, or broken up into irregular, pointed fragments of lead. In the case of shots fired from a short distance the bullet is heated to a very high temperature, and, as we shall see, it is under these circumstances that its explosive action is most likely to take place.

Bullets cause the following injuries: 1. The mildest form of gunshot injury is contusion of the soft parts, with suggillation and without a wound. These contusions of the skin or soft parts are usually made by spent balls coming from a great distance. In rare cases subcutaneous fractures are also produced in this manner. Occasionally the contused, undivided skin is pressed inwards like a pouch, thus causing, when the bullet strikes upon the abdomen, contusion and laceration of internal organs, of which the liver may be one. Moreover, bullets which have a great velocity can be so checked by striking a watch, purse, pocketbook, pieces of leather on the uniform, etc., that only a contusion without any wound results. Bullets of small calibre with a covering of nickel or steel cannot be stopped in this way, as they have an extraordinary penetrating power.

2. *Furrowed wounds* are caused by bullets which graze the surface of the body and carry with them a portion of the skin, so that a more or less deep furrow is formed.

3. The most common gunshot injuries are *tubular wounds*—i. e., the ball passes through the skin and enters the soft parts, where it either remains lodged (so-called blind shot canal) or comes out again at another part of the body ("seton shot"), thus making an opening where it entered and one where it emerged. The differentiation of the points of entrance and exit is of importance notably from a medico-legal point of view. The point of entrance is usually more or less indented, depending upon the size of the bullet, and is coloured bluish-black, while the exit opening is generally smaller, and looks more like a tear. These points of difference do not, however, always hold good, as the opening of exit is sometimes larger than that of entrance, particularly when a bone is splintered or when the ball changes its shape or becomes broken into pieces. Occasionally several points of exit are found, especially if the bullet has been fired at short range—a thing which produces an effect like an explosion, shattering the bone into separate splinters, which perforate the skin. The burning of the integument is often very extensive when the revolver or pistol has been dis-

charged close to the body, as in attempts at suicide, and then, owing to the healing into the tissues of small particles of powder, the skin often remains of a greyish-black colour for the rest of life. The same is true of small shot, which, when fired from near at hand, can also cause very extensive destruction of the region where they strike, and particularly severe shock, giving rise to such marked symptoms of collapse that the patient may die soon after the injury. Quite recently I saw a bad case of collapse occasioned in this way, in a hunter who was struck by fifty-two pieces of shot; but in spite of having sustained wounds of his lungs, pericardium, and intestine, the patient recovered.

The direction of the canal formed by the ball in its passage through the body is sometimes very peculiar, and instances are recorded where it encircled the thorax close to the ribs without injuring the pleura or the lungs. The entrance into a gunshot wound of unclean foreign bodies, such as bits of cloth, leather, or linen from the clothing, has a very important bearing upon the subsequent course of the injury, as substances like these are extremely apt to give rise to infection provided the micro-organisms they contain are not killed by the intense heat of the bullet.

The modern artillery projectiles, such as grenades, cannon balls, shells, etc., often give rise to severe injuries similar to those caused by machinery in times of peace; entire extremities may be torn from the body, and death can be instantaneous. But slight wounds, such as contusions and superficial lacerated wounds, are likewise frequently caused by the same missiles.

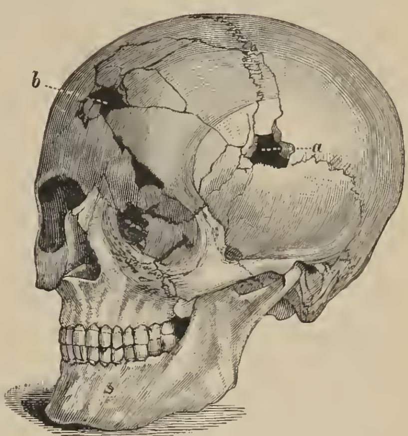


Fig. 397.—Gunshot injury of the skull (in a Russian soldier killed Aug. 30th, before Plewna), with numerous fissures which run from one opening (*a*) to the other (*b*) (Bergmann).

The gunshot injuries of bone are, as a rule, (1) *compound comminuted fractures.* The number of fragments is sometimes very large, and, in addition, there are many fissures, as illustrated in Figs. 332, 336-338, 397. The splinters of bone are often driven into the soft parts or even through the skin, forming, as we stated before, several exit openings. Not infrequently the bone is crushed to a pulp.

There are also found in bone (2) *tubular gunshot wounds* or punched-out wounds, with or without splinters or fissures. The latter,

in Fig. 397, unite the points *a* and *b* of entrance and exit of the missile. (3) *Subcutaneous fractures* caused by a spent ball have already been spoken of. The mildest form of injury to bone is (4) *contusion*, with an extravasation of blood into the periosteum and bruising of the bone substance. Sometimes hollows or depressions, together with fissures, are formed in the bone against which the bullet is flattened out, or the latter is found impacted, being in some cases split in two and seated astride of the broken edge of a fragment (Fig. 398).

In rare instances a gunshot fracture takes place not directly at the point where the bullet strikes the bone, but at some distance from it, and either exists by itself or is combined with a fracture at the point where the bullet struck (Lacronique). These indirect gunshot fractures may result from a bend, a twist, or concussion of the bone in question, and occasionally by a union of several of the fissures which radiate from the point where the bone has been struck by the bullet.

Gunshot injuries of joints are in the main complicated wounds with or without injury of bone. The most severe gunshot injuries of the joints are those with splintering of the articular ends of the bones.

The Effects produced by Modern Projectiles.—Bush, Kocher and others have made some interesting experiments pertaining to the action of projectiles constructed of lead and the kind of damage they cause in the tissues; and Reger has recently studied the action of such projectiles upon bone, and has come to some practically important conclusions. In the case of injuries made by soft lead within a range of four hundred metres, an effect is produced which is like an explosion; the wound is funnel-shaped, and the bone is crushed to fragments, which penetrate the soft parts posteriorly, making the opening where the projectile emerges ten to twenty times as large as the opening where it entered. In the case of gunshot wounds made at a range of five hundred to one thousand metres, a clean-cut, penetrating wound is made, with or without radiating fissures. If the projectile traverses the longitudinal axis of the bone, extensive splintering of the latter may be produced. In the case of wounds made at a range of one thousand to fifteen hundred metres, comminuted fractures with considerable shattering of bone not infrequently occur in spite of the diminished momentum of the projectile. At longer ranges there is a slight splintering or contusion of the bone, in which the bullet will often be found impacted (Fig. 398).

The Action of Projectiles of Small Calibre (Eight Millimetres in Diameter) with a Steel Coating.—Chauvel, Bovet and others have made experiments with the new small calibre (eight millimetres in diameter) projectiles covered with nickel or steel, which have lately been introduced into the European armies. All the experiments show that these new projectiles have a great penetrating power on account of their tremendous velocity, and this has been still further increased by the use of the new smokeless powder. The projectiles which are coated with steel retain their shape, while those made of lead become flattened on account of their comparative softness, and when dis-

charged at a short range show a considerable explosive effect. At short ranges, however, the action of the projectiles which are covered with steel and those made entirely of lead is very much the same, except that the penetrating power of the former is greater, being sufficient to pass through several cadavers placed one behind the other. According to Bruns, these steel-coated projectiles can pass through iron plates twelve millimetres in thickness, or pine wood one hundred and ten centimetres thick, at a range of twelve metres. At a range of four hundred metres Bruns found that they produced an effect like an explosion upon the skull only, the long hollow bones not suffering such extensive injury; at a range of eight hundred metres perforating wounds occurred ; and even at a range of twelve hundred metres two or three parts of a body placed one behind the other were completely shot through. The projectiles rarely remain in the body, as Hobart and Chauvel have noted by experiments made at ranges as long as fifteen hundred to two thousand metres. In general, the modern projectiles of small calibre which are covered with steel are more humane than those made entirely of lead, and, except at the ranges where explosion of the projectile takes place, the wounds they make have a more favourable prognosis, since the bullets do not become shattered, but make a smooth puncture with small openings. The firearm of small calibre is the most powerful weapon of modern times, on account of its great velocity, long range, and tremendous penetrating power.

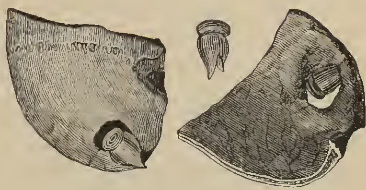


Fig. 398.—Impaction and splitting of lead bullets in bone (Bergmann).

The observations made upon living men with projectiles of eight millimetres diameter correspond very closely with those mentioned above (Stitt). Up to certain ranges (twelve hundred to two thousand metres) projectiles which strike the body directly pass entirely through it, forming small openings at their points of entrance and exit; but if, before entering the body, they rebound from a rock or piece of iron, they rarely do this. In these rebounding shots the steel-covered bullets lose their shape and become bent, the steel covering bursts, etc., and, accordingly, the wounds they make are torn and mangled, and the openings they form on entering and coming out are much larger.

The Course of Gunshot Wounds.—The course of gunshot wounds may be inferred from what we have already said of injuries to the soft parts, bones, and joints, and the reader is referred to the paragraphs which treat of these subjects. The pain is usually trifling, as the wound is made so quickly, and often a person does not know that he has been hurt until he notices the blood. The hæmorrhage may be very slight even when large, deep-seated arteries have been injured, and it ceases spontaneously by the formation of a thrombus and by the pressure of the surrounding parts. In other cases the wounded person dies in a few minutes, or even sooner, if a large artery such as the femoral or the carotid has been divided.

The subsequent course of a gunshot wound depends upon whether, at the time of the injury or afterwards, infectious substances (bacteria) have gained access to the wound by means of dirt of various kinds, pieces of clothing, or unclean fingers, instruments, etc. The temperature of the projectile at the moment when it struck the body is another matter which has an important bearing upon the course of the wound, as the micro-organisms are often killed by the heat of the ball, especially if it is of small calibre and has a nickel or steel covering. Hence infection of gunshot wounds on the battle-field is almost always due to the fact that immediately after the injury, or not until later, micro-organisms gain access with the dirt, or from insufficiently disinfected fingers and instruments. This infection may give rise to the various diseases of wounds, such as progressive inflammation and suppuration, sepsis, and pyæmia. Tetanus is also not infrequently observed, especially if earthy materials have come in contact with the wound. If, however, infection does not take place, even very extensive injuries to bones and joints heal readily.

Gunshot wounds inflicted at a short range, in which both soft parts and bone are badly mangled, have the worst prognosis, and in many cases, especially in wounds involving the trunk, head, or abdomen, death is instantaneous. If a patient with a gunshot wound of an extremity remains alive, a conservative plan of treatment is usually hopeless, and amputation or disarticulation is indicated. It has already been remarked that the modern steel-coated projectile of small calibre, in spite of its great penetrating power—leaving out of consideration the range within which it explodes—makes a cleaner wound than the old-fashioned soft lead projectile, which mangles and lacerates both bone and soft parts.

Treatment of Gunshot Wounds.—Gunshot wounds are treated, in general, according to the same principles which we have already given for the treatment of injuries to the soft parts, bones, and joints. Nevertheless, I shall discuss the treatment of gunshot wounds somewhat more at length, with particular reference to their treatment in times of war. For the special treatment of penetrating wounds of the head, thorax and abdomen the reader is referred to the Special Surgery.

We think with a shudder of that period of the middle ages when gunshot wounds were wrongly looked upon as poisoned wounds, and were therefore burned out with boiling oil in order to destroy the venom of the powder. Ambroise Paré and Maggi successfully combated this method of treatment in 1551 and 1552. The story is told that when the army of King Francis of France stormed the little castle

of Villane, near Susa, Ambroise Paré did not have sufficient hot oil at hand to burn out all the gunshot injuries in accordance with the treatment then in vogue. On the next day all those wounds which had not been burned out with oil were free from pain and inflammatory swelling, while those which had been thus treated were very painful and much swollen. After this experience Paré always denounced this cruel method.

Every gunshot injury should, of course, be treated according to antiseptic principles, although this is quite a different thing in times of peace from what it is in war, when, on account of the great numbers of the wounded, it is not possible to attend to every case as carefully as we are ordinarily accustomed to. It is hence very natural that the expectant treatment of gunshot injuries has again been recommended for military practice.

It is especially important to check the hæmorrhage and remove all foreign bodies that may have gotten into the wound, such as bullets, unclean pieces of clothing, etc. But it is a bad plan to hunt for the bullet too industriously or too long, as they subsequently become healed up in the tissues, just like other foreign bodies. Dementjew and Bergmann saw in the Russo-Turkish War eighteen cases in which the ball healed up within the knee joint. Subsequently the projectiles sometimes leave their original position and wander about, like needles or other similar bodies. Bergmann and Reyher made very successful use of the expectant treatment during the Russo-Turkish War, even in cases of injuries involving joints. They confined themselves to a disinfection of the wound and its neighbourhood, and then immobilised the extremity in plaster of Paris with or without an antiseptic occlusive dressing. The parts often united *per primam intentionem*, the bullet becoming enclosed, while in other instances suppuration took place, and yet the bullet remained where it was. The expectant plan of treatment may be accompanied by dangers when there are pieces of clothing in the wound; but these form the minority of cases, and there are usually no such sources of infection present. If one decides to adopt operative measures and enlarge the wound, in order to check hæmorrhage, for example, or on account of inflammation or suppuration, one must, of course, proceed according to general antiseptic principles. In civil practice one will not make so much use of the expectant form of treatment for gunshot fractures, but will follow the ordinary rules which govern the management of compound fractures. In cases of wounds inflicted at short ranges with extensive mangling of the soft parts and bone, conservative treatment is usually hopeless, and amputation is in general indicated; while for wounds inflicted at long ranges

the conservative method should first be tried, as it is in such cases that it has been shown to be most useful.

It is especially important that the wound should not be examined with fingers or instruments which have not been disinfected, except, perhaps, in the face of serious hæmorrhage which threatens the patient's life. Many a wounded person has lost his life through examination of his injury with a finger or a probe which had not been properly disinfected. Reyher is right in discriminating between "fingered" wounds—i. e., those which have already been examined by a physician—and "unfingered" wounds—i. e., those which come directly under the surgeon's care. Out of eight patients with "fingered" injuries of the knee, six died and one was in great peril, while of seven "unfingered" injuries of the knee six recovered.

The primary antiseptic treatment consists either of antiseptic occlusion of the wound in the skin or antiseptic drainage. In the former—i. e., in healing under a scab—all exploration of the wound with a probe or the finger should as far as possible be avoided. If, however, an exploration of the wound is absolutely necessary on account of dangerous hæmorrhage, infection of the wound, etc., drainage must at the same time be provided for, and any operative measures which may be necessary, such as removal of splinters of bone, resection, or amputation, must be undertaken at once. An excellent method of drainage in case of large gunshot wounds is to pack the latter with iodoform gauze or sterilised mull; the best antiseptic for military practice is probably bichloride of mercury. The drainage should be as simple as possible. It has been suggested that each soldier be supplied with the material for the first dressing in the form of a small bundle which can be sewed into his coat or carried in the breast pocket or knapsack, and that he should also have with him some antiseptic powder, such as iodoform. I think this plan of letting each soldier apply the first dressing with the materials which he carries with him is a bad one, since these dressings are anything but antiseptic—in fact, they are usually full of dirt. It is much better that there should be a large number of surgeons and well-trained assistants upon the field furnished with sufficient antiseptic dressing materials, and that the dressings which the soldiers carry with them should only be used in an emergency. These consist of two pieces of compress impregnated with bichloride, one bandage, a safety pin, and a three-cornered piece of cloth, all of which are wrapped up in some rubber material. In order that antisepsis may be properly observed in time of war all persons entrusted with the care of the wounded should be previously instructed in the general principles of antiseptic treatment and in the technique of applying simple antiseptic dressings. The vol-

untary assistance of persons in the higher walks of life, especially students, is very desirable in this connection.

The sterilisation of dressings can be carried out in times of war according to the same principles as in times of peace, and hence it is not a good plan to make a collection beforehand of dressing materials which have been impregnated with antiseptics, as they will be subsequently found to contain bacteria in spite of the best of packing. The most suitable kind of dressings are those which can be transported in the smallest possible bulk, such as mull, hemp, and cotton. The common salt-bichloride tablets which Angerer has recently recommended for military practice are very useful, and greatly facilitate the preparation of permanent bichloride solutions. Instead of sponges, aseptic gauze pads impregnated with bichloride of mercury may be used.

On the battle-field the wounded are first carried to a protected spot, marked by a white flag with a red cross, where temporary dressings are applied, so that they can be transported to the field hospital situated near by. At the first place only the operations necessary to save life should be performed, such as arrest of hæmorrhage and amputation. The most seriously wounded, especially those who cannot get to this place by themselves, should be attended to first. In future battles the disproportion between the number of the injured and that of the surgeons will be even more evident than it has been in the past, as the rapid-firing guns now used, on account of the greater accuracy of their aim, will probably increase the numbers of the wounded, while the number of surgeons will remain about the same. Hence only those operations will be performed which are absolutely necessary. Billroth likewise expressed the fear that the number of wounded in coming battles will be so great that there will not be sufficient help at hand to render them the necessary assistance while the battle is going on. Haase states that the organisation for the care of the wounded which the German army possesses will amount in future wars to forty-five thousand well-trained men (hospital orderlies, carriers of the wounded, etc.). Thus we can see that a liberal provision has been made. At the field hospitals, which are usually churches, school-houses, or other large buildings, or tents and barracks, the wounded who are brought in with temporary dressings on are examined with antiseptic precautions and permanent dressings then applied, and, when necessary, the wounds are enlarged, drained, and disinfected. Those who have thus been dressed antiseptically are then transported to a permanent hospital. During transportation injured portions of the body, especially gunshot fractures, must be immobilised as thoroughly as possible (see § 53 and page 219).

In addition to tents, Döcker's barracks are particularly well adapted

for quarters for the wounded. Haase states that an army of 100,000 men need 601 movable and 167 stationary barracks to furnish room for from 15,000 to 18,000 wounded. Some of the barracks used for war purposes are made of felt (Döcker's barracks), while others are tents or wooden sheds. Haase is right in recommending that these tents and barracks be put in position by bodies of men organised for that purpose and under the command of special officers.

We have not space to take up more in detail the first treatment of the wounded on the battlefield, but whoever is interested in this subject should consult the books which have been written upon it by Esmarch and Port. A very excellent and exhaustive treatise on military surgery will be found in Fischer's Handbuch der Kriegschirurgie (Deutsche Chirurgie, Stuttgart, 1882). For a description of the easily transportable operating table which I have devised for military practice, see page 7, Figs. 4 to 6.

Fig. 399.—American forceps for extracting a bullet.

Search for a Ball.—In searching for a ball one may use the finger or an ordinary probe, and in the case of very deep wounds, long, curved or straight dressing forceps, silver catheters, etc. Graham Bell has invented an electric probe for finding bullets. A needle which has been insulated by coating all but its point with varnish is inserted into the region where the presence of the projectile is suspected and then connected with the end of a telephone wire. A metallic plate of the same material as the needle is fastened to the end of the other wire and applied to the skin in the neighbourhood of the bullet. If the point of the needle comes in contact with the ball the circuit is closed, and every time they come together a distinct noise is heard in the telephone. Klein has constructed a similar electro-microphonic searcher (see Aerztl. Polytechnik, March, 1892). The magnetic needle can also be used in suitable cases for finding a ball even after it has become healed up in the tissues, and is especially applicable to the search for the modern steel-coated projectiles. Gärtner recommends that the steel-covered bullet which has entered the body be first magnetised by stroking the area in question with a powerful magnet. By means of a sensitive magnetic needle—i. e., a pair of astatic needles suspended by a silk thread, or Lamont's magnetoscope—the point on the skin is determined to which the ball or iron splinter lies nearest (Kocher, Gärtner, Sachs). Gärtner constructed an astatic magnetic needle out of a magnetised sewing needle which he broke in two, a straw, and a piece of silk thread, and made successful use of it in finding projectiles after having first magnetised them. The old-fashioned probe invented by Nélaton has a knob made of porcelain which is made black by contact with the bullet.

Projectiles are extracted by means of forceps, or spoon-shaped instru-

ments. The most simple kind are the long, curved or straight dressing forceps, or long, narrow forceps with sharp-pointed teeth which cover one another when closed (Fig. 393), so that they do not injure the tissues but become inserted into the lead when they seize the ball. The best-known spoon-shaped instruments are Thomassin's and Langenbeck's. Elevators can also be employed for this purpose. Formerly, if the ball were firmly embedded in the bone, it was extracted by screws or augers, which were bored into the lead like corkscrews. These augers and screws, and the forceps with the sharp-pointed teeth, are no longer used for the modern steel-coated projectiles, having been superseded by narrow, straight, or curved forceps. The steel covered projectiles, however, remain lodged in the body much more rarely than the lead bullets; they usually pass entirely through it and emerge externally.

CHAPTER V.

TUMOURS.

Tumours in general.—Definition and classification of tumours.—Etiology of tumours.—Clinical features, diagnosis, prognosis, and treatment.—The anatomical structure and clinical course of the different varieties of tumours, with their treatment.

§ 125. **Tumours in General—Definition and Classification.**—The study of tumours forms one of the most interesting chapters of pathology; but it would require too much space to discuss this vast subject with anything like completeness, and so we must satisfy ourselves with merely a superficial account of such tumours and growths as are amenable to surgical treatment. I must refer the reader to the excellent text-books of Virchow, Waldeyer, Cohnheim and others for a description of the general pathology and anatomy of neoplasms.

The question, What is a tumour? has received various answers. In fact, it is difficult to give a suitable definition which includes all tumours, as they present marked differences anatomically, etiologically, and clinically. Lücke's definition has been the most widely accepted. According to him, we mean by a tumour an increase in the volume of some portion of the body, due to a new formation of tissue which reaches no physiological limit, and which—to add Cohnheim's words—differs from the morphologico-anatomical type of the locality where it occurs. We distinguish from true tumours the hyperplastic, inflammatory formations, all the infectious granulation tumours of tuberculosis, syphilis, leprosy, etc., and certain collections of fluid and cells in preformed cavities, such as aneurysm, hygroma of tendon sheaths and mucous bursæ, hydrocele of the tunica vaginalis testis, and all retention cysts. We recognise, as Cohnheim does:

1. Tumours the main portion of which is of the connective-tissue type; these include fibroma, lipoma, myxoma, chondroma, osteoma, angeioma, lymphangeioma, endothelioma, lymphoma, and sarcoma, together with mixed or combination tumours made up of simpler forms.

2. Tumours having the type of muscular tissue: Myoma lævicellulare and myoma striocellulare.

3. Tumours made up of nerve tissue: Neuroma and glioma.

4. Tumours of the epithelial type—viz., epithelioma, onychoma, adenoma, cystoma, and carcinoma. There remains as a subdivision of this group the teratoma of Virchow, in which many different kinds of tissue—such as hair, skin, bone, teeth, parts of intestine and brain—are found. In this class belong the dermoid cysts.

Birch-Hirschfeld makes the following classification: 1. Connective-tissue tumours; 2, muscle tumours; 3, nerve tumours; 4, epithelial tumours; 5, mixed or combination forms of tumours; 6, cystic tumours, consisting of a closed sac containing more or less fluid. This group includes tumours which are etiologically and histologically very different; some of them (retention cysts) do not belong to the proliferating tumours at all, while others are due to abnormities of development (teratoma-dermoid cysts), or originate secondarily from different tumours (cystoma glandulare, cystosarcoma). 7. Infectious tumours (granulation tumours) which are related histologically and etiologically to the inflammatory formations, and do not belong amongst the true tumours (products of tuberculosis, syphilis, leprosy, etc.).

§ 126. **Etiology of Tumours.**—The etiology of tumours, meaning thereby neoplasms, still remains obscure, although many theories have been advanced upon this subject. Their causes are partly direct and partly indirect or predisposing, the latter including the effects of age, sex, occupation, etc. Esmarch thinks that inherited predisposition plays an important part in their causation, and in many cases—notably of sarcomata—he believes that their development depends upon a predisposition inherited from syphilitic ancestors. As direct causes of tumours, local irritations—mechanical, chemical, or inflammatory in nature—have been thought especially important. Thus we know that a sarcoma, for instance, occasionally forms after a severe contusion, or that an epithelioma of the lower lip or of the mucous membrane of the mouth develops in immoderate smokers, or as a result of frequently repeated traumatic irritations caused by a sharp tooth, frequent shaving with dull razors, etc. A similar explanation is given for the origin of the epithelioma which is met with upon the scrotum of chimney sweeps and people employed in the manufacture of tar and paraffin. Sometimes after fractures benign (osteoma, chondroma) and malignant tumours (sarcoma) develop in the callus—the so-called callus tumours. According to Rapok, one hundred and twenty-eight out of six hundred and sixty-nine tumours followed injuries. But the number due to this cause alone is, as Ball and Winiwarter state, not large, nor is mechanical or chemical irritation sufficient in itself to produce one; first of all there must be present a predisposition of the part in ques-

tion to the development of a tumour, and it is this that is really the determining cause of tumour formation. Sometimes disturbances of the nervous system—trophoneuroses—play an important part in their causation. Buchterkirch and Bumke saw a case of multiple, symmetrical lipomata which followed a contusion of the spinal cord. A preceding inflammation has a very important influence upon the development of neoplasms, as is shown in those cases of carcinoma of the breast which follow a mastitis. Malignant tumours, both carcinoma and sarcoma, often originate from simple warts, and melanomata from small patches of pigment in the skin. Rapok states that one hundred and eighty-two out of three hundred and ninety-nine carcinomata started in warts, and indeed one third of all the instances of tumours collected by him (six hundred and ninety-nine) had this origin. According to Woodhead, tumours are due to a deficiency — not a superfluity — of nourishment; even though there is actually an increased amount of food taken into the system, this is not able to supply the needs of the tissues in question. He holds the view that tumours develop when, as a result of irritations from different sources—such as injuries, parasites, microbes, long-continued action of an irritating organic or inorganic substance, or a simple chronic catarrh—so great an increase in the activity of the tissue elements is demanded that the food brought into the system is insufficient to supply these demands. Schleich looks upon tumour-formation as a kind of infection originating within the organism, a cell at a certain stage of its physiological development becoming infectious as a result of irritations of various sorts. Analogously to the development of an impregnated ovum, tumours are considered by him as products of a pathological conception and impregnation ; the pathological spermatozoon is represented by the cell that has become infectious. Many authorities think that tumours are caused by micro-organisms, and we shall consider this question when we take up carcinomata.

Cohnheim developed a very ingenious theory as to the ultimate cause of new growths. He thought this to be an abnormity or irregularity in the embryonic rudiment of the part of the body in question—in short, that neoplasms originate from the growth of embryonic germs or germinal cells which have been, as it were, shut up in the normal tissues. In many individuals these tumour germs do not become developed, but in others traumatisms, mechanical and chemical irritation, or the diminished powers of resistance possessed by the surrounding normal parts, increased blood supply, etc., may arouse them to activity. This theory of Cohnheim's seems very plausible for many cases, but it lacks anatomical foundation ; in fact, as Birch-Hirschfeld says, a positive proof

of the correctness of Cohnheim's hypothesis, as applied to tumours in general, is quite impossible. It is, however, unquestionable that some tumours spring from embryonic germs, and certain facts are very well explained by Cohnheim's theory—viz., the transmission of tumours by inheritance, the occurrence of congenital tumours, and of certain tumours in particular portions of the body, such as epithelial tumours, carcinomata of the lip, tongue, cardiac or pyloric orifices of the stomach, glans penis, portio vaginalis, cervicis, etc.; in other words, in localities where inversions of the epiblast in the form of groups of epithelial cells, which have strayed away during the embryonic period, may easily take place. Cohnheim's hypothesis also furnishes the best means of explaining the heterologous origin of primary epithelial tumours in organs which do not contain epithelium. We know, for instance, that the dermoid cysts are a result of stray embryonic germs. But tumours probably do not have an unvarying etiology. As Ziegler has said, new growths arise from different tissues, these being (1) embryonic tissue, (2) growing tissue, (3) fully formed tissue, and (4) tissue in the stage of retrogression. In early life, connective-tissue tumours predominate, as a rule; in old age epitheliomata and carcinomata.

Transmissibility of Tumours.—Great importance attaches to the question whether or not tumours, especially malignant ones (carcinoma, sarcoma), are transmissible in the sense that living tumour-cells, when transplanted, can give rise to the development of the same kind of malignant tumour in that part of a body to which they are transferred. Such a transmissibility of tumours has in fact been sufficiently proved in the case of both animals and man by experimental and clinical observations. Eiselsberg successfully inoculated rats with a fibro-sarcoma. In regard to the transmissibility of carcinoma see page 781; of melanoma, page 770.

Etiology of Tumours in Animals.—Plicque has published, in regard to the origin of tumours in animals, some interesting facts which show many analogies to tumour-formation in man. The real cause of tumours in animals is, to be sure, unknown, as far as the predisposition of the bearer is concerned. But as regards the direct cause, the following has been noted: The carcinoma of the lip in horses generally develops in the corners of the mouth from pressure of the bit, while in cats the upper lip is ordinarily affected as a result of the repeated bites of small animals. The subcutaneous fibroma which is often seen in horses is caused by the pressure of the harness. Constant or frequently repeated traumatisms play an important part in the origin of tumours in animals, as do also preceding inflammations. Bitches suffer from carcinoma of the mammary glands much oftener than male dogs, and the hindermost glands are the ones most commonly affected, as they are particu-

larly likely to be the seat of a mastitis. The melanosis of horses is thought to be transmissible by inheritance, so that mares or stallions which have it cannot be used for breeding; heredity is also said to play a part in the origin of the mammary cancer of bitches.

The influence of age is very noticeable in animals. In old dogs carcinoma is very frequent, while young ones are practically immune. Whether the nutrition of the animal plays a part in the tumour-formation, as has been thought to be the case in carcinoma in man, cannot, as Plicque says, be easily decided. Amongst pronounced carnivora like the dog, carcinoma is very common, and herbivora like the horse are not exempt when they reach an advanced age.

§ 127. **Growth, Course, Diagnosis, and Treatment of Tumours.**—The growth of tumours takes place in exactly the same way as that of other tissues—by cell proliferation. The rapidity of growth is very variable, depending upon the locality, the blood supply, and the structure of the tumour. The more cells the latter has, the more rapidly it grows. Localised or more diffuse disturbances of nutrition, such as fatty degeneration, calcification, and colloid degeneration or necrosis, resulting, perhaps, in a complete spontaneous cure of the tumour very frequently occur. Necrosis which takes the form of ulceration is exceedingly common, especially in carcinomata which have broken through the skin or mucous membrane. According to Nepveu and Verneuil, the softening of tumours is caused in some instances by bacteria. A true tumour does not disappear spontaneously; some remain stationary, while others keep on growing at a faster or slower rate. The most important distinction between tumours is presented by their clinical course, and this allows us to divide them into benign and malignant growths. The former remain local, but the latter penetrate into the neighbouring tissues and destroy them, and the tumour germs, being carried off in the blood and lymph, give rise to metastatic or secondary neoplasms in all parts of the system, especially the liver and lungs. Cartilage is the only tissue in which, so far as I know, no metastases have been found. The metastases have essentially the same structure as the primary tumours, and are found either in the vicinity of the latter—that is, in the region supplied by the lymph and blood which come directly from the tumour—or in distant organs after the tumour germs have passed through the heart. Metastases due to capillary emboli are most commonly caused by the tumour cells which pass through the lungs in the venous blood without being retained there (Zahn). Should the germs be carried through the lymph vessels, they usually become implanted in the nearest lymph glands and here lead to the development of tumour tissue which is identical with that of the original neoplasm. In this way the infected lymph glands become new foci for

further infection and development of metastases. The tumour germs also enter the vascular system by a direct ingrowth of the mother tumour into the walls of the vessels. I once saw a metastasis in a valve of the femoral vein in a case of sarcoma of the leg. Tumours which in other respects are benign—such as fibroma, lipoma, cystic goitre, chondroma, myoma, etc.—may also, in exceptional instances, give rise to metastases. It is characteristic of tumour metastases—especially those from the really malignant tumours—to go on growing indefinitely. Normal tissue germs do not have this peculiarity, as is shown by the experiments of Cohnheim, Maas, etc. Small pieces of periosteum and embryonic cartilage implanted in the circulation, the peritoneal cavity, or in the anterior chamber of the eye, grow for a time and can thus give rise to very small osteomata or enchondromata; but these soon disappear without leaving any traces. If, on the other hand, living tumour cells from a carcinoma or sarcoma, for example, are inoculated upon animals, they go on developing, and give rise to tumours which are the same as the original ones. Man also may become infected with the germs of tumours, and this has occurred during operations for their extirpation. Carcinoma and sarcoma are the typical malignant tumours; they lead to local destruction of tissue and to general infection of the body by the formation of metastases. They are especially the ones which so commonly reappear at the original site after they have been extirpated. These recurrences are, according to Thiersch, due partly to tumour germs which were not removed, though in other instances we have to deal with a new tumour—a so-called regional recurrence—similar to the one that was removed, which makes its appearance in the cicatrix or near by, months or even years afterwards. Then, again, recurrences may be due to the inoculation at some point of living tumour cells during the extirpation of the primary tumour. It can easily be understood that a benign tumour may also prove fatal to the bearer on account of its position, as exemplified by an osteoma on the inner tablet of the skull.

The evil effects of tumours upon the organism are partly local and partly constitutional in character. Those in particular which grow rapidly are a great drain upon the system. The part which is affected may be entirely destroyed, and the formation of metastases, together with the necrosis and ulceration undergone by the tumour, may involve different organs and eventually lead to an increasing general cachexia, to which the patient will succumb. This cachexia, manifesting itself in the form of general disturbances of nutrition, loss of flesh, and marasmus, appears in malignant tumours which are accompanied by local destruction of tissue and metastases. Rommelaire and Ranzier

have found that the excretion of urea is diminished in all malignant tumours, and may ultimately become less than twelve grammes *pro die.* The degree and rapidity of development of the cachexia depends upon the location of the tumour, its condition (ulceration, necrosis, hæmorrhage), and the age and constitution of the patient. The malignancy of the infectious tumours varies very considerably. Some, like epithelioma of the lip and the flat skin cancer (*ulcus rodens*), spread but slowly to the nearest lymph glands, while others—carcinomata and sarcomata, for instance—go on very rapidly to the formation of metastases in internal organs. The above-mentioned gradual diminution in the excretion of nitrogen, which is met with in malignant tumours, may occasionally have great value in determining the need and prognosis of surgical interference, especially if the decrease in the amount of urea is marked, in which case operative procedures are contraindicated.

The Possibility of curing Malignant Tumours (*Carcinoma and Sarcoma*).—A variety of statements, based upon statistics, have been published relating to the curability of the malignant tumours. Fischer and Meyer have written an especially interesting article on this subject. Of two hundred and ninety-eight cases of malignant tumours operated upon by Rose in the hospital at Zurich between 1867 and 1878, Meyer was able to get reliable returns from sixty-four. Of these sixty-four, twenty-two were alive in 1887 without recurrence, and showed a period of exemption varying from nine years and seven months to twenty years and three months. Nineteen died without recurrence, the period of exemption varying from one and a half to sixteen years. In the remaining five patients the cause of death could not be ascertained. Amongst the cases of cure were some exceedingly serious ones, involving very extensive operations, with removal of recurrent tumours and diseased lymphatic glands. Sarcoma, cysto-sarcoma, and fibro-sarcoma showed the longest period of exemption, while carcinoma showed the fewest instances of permanent cure. In rare cases of sarcoma of the skin and multiple melanosarcoma, spontaneous retrograde changes have been observed which have resulted in the complete and permanent disappearance of the tumours (Hardaway).

Diagnosis of Tumours.—The diagnosis of tumours is not always easy. By means of inspection, palpation, and examination of the subjective symptoms we try to form as correct an idea as possible of the location and structure of the tumour. The location of a neoplasm often enables us to determine its nature. Very often a differential diagnosis must be made between an inflammatory process and a new growth (see page 251, Diagnosis of Inflammation). In doubtful cases puncture with a hypodermic needle may be necessary. It is often very important to

determine before the operation whether the tumour is benign or malignant, in order to decide upon the kind of operation to pursue. In suitable cases—for example, in growths within the larynx probably carcinomatous in nature—parts of the tumour are removed and examined microscopically. Syphilis, tuberculosis, and other chronic infectious diseases must always be considered in making a differential diagnosis, as a large number of the connective-tissue tumours—such as certain so-called sarcomata of muscle, many spindle-celled sarcomata, neuromata, keloids, and malignant lymphomata (Esmarch)—are gummata, and can be cured by an antisyphilitic treatment.

General Treatment of Tumours.—The general rule in regard to the treatment of tumours—which we shall later discuss more fully in speaking of the individual tumours—is that they should be removed as quickly and as thoroughly as possible. The sooner a malignant tumour is radically excised the better is the prospect of a complete and permanent cure. The possibility of the total removal of a tumour depends upon its location and the kind of organ involved. In malignant tumours, especially carcinoma, the neighbouring lymph glands should also be removed, even though they are not diseased, and after every *amputatio mammæ* for carcinoma the lymphatic glands and surrounding fat in the axilla must likewise be extirpated. The removal of tumours is accomplished usually by the knife, though occasionally by the galvano- or thermo-cautery, red-hot iron, ligature, *écrasement*, etc., methods all of which have been sufficiently described in §§ 24–44.

In proper cases Péan recommends the removal of the tumour in pieces (*morcellement*). The method consists mainly in first rendering the tumour as bloodless as possible by the use of differently formed clamps applied around its circumference, after which the growth is excised in portions, and, if possible, the wound is sutured while the forceps are still in place. The latter can then usually be taken off and the wound dressed. In other cases Péan leaves the forceps in position for twelve to forty-eight hours. An almost bloodless operation can thus be performed even in the case of very vascular tumours.

The encapsulated, myelogenic, giant-celled sarcoma of bone can in suitable cases be removed by cutting away only the anterior half of the bony capsule by means of the chisel and hammer, or the saw, and then carefully scraping out the tumour mass with a sharp spoon. Nussbaum has lately made use of the thermo-cautery for the destruction of malignant tumours like cancers. By circumcision with the thermo-cautery in cases of inoperable, malignant neoplasms, the patient can be helped very materially; the growth of the tumours is thus diminished, the pain caused to disappear, and any carcinomatous ulcerations are im-

proved and their decomposition checked. In cases of sloughing, inoperable carcinomata, the removal of the softened portions with the sharp spoon and the subsequent application of the thermo-cautery give good results.

Many attempts have been made to destroy tumours, especially inoperable sarcoma and carcinoma, lymphoma and myoma, by means of parenchymatous injections of absolute alcohol, tincture of iodone, ergotine, acetic acid, nitrate of silver, arsenic, turpentine, osmic acid, phosphorus, etc. Turpentine is injected with equal parts of absolute alcohol, or one part of turpentine to two parts of alcohol, from a half to a whole hypodermic syringeful about every ten to fourteen days. This is usually followed by the formation of abscesses which cause a variable amount of shrinkage in the size of the tumour. Some three drops of a one-per-cent. solution of osmic acid is injected every day. Arsenic can be given in the form of Fowler's solution, either internally or subcutaneously. Internally one begins with ten drops daily, and increases the dose two to three drops every third day. About two drops of Fowler's solution, undiluted, are injected into the tumour daily, or ten drops of the undiluted solution once a week. The solution may be diluted two or three times for susceptible patients. The arsenic treatment was recommended by Billroth, especially for malignant lymphoma. Mosetig-Moorhof finds the parenchymatous injection of aniline dyes (pyoktannin, methyl violet, 1 to 500) very useful in malignant tumours (carcinoma and sarcoma), but the success which he has reported has not been experienced by other surgeons (Billroth); on the contrary, bad results, such as premature softening, rupture of the tumours through the skin, sloughing, etc., were obtained. The treatment of tumours by parenchymatous injections was first introduced by Thiersch. In cases of inoperable tumours erysipelas has been inoculated by means of cultures of the erysipelas coccus, after Busch had observed that, as a result of erysipelatous inflammation, tumours, such as sarcoma of the face or neck, disappeared by fatty degeneration. Janicke and Neisser were able to demonstrate by microscopic examination, in a case of carcinoma with fatal erysipelas due to inoculation, that the cancer cells are actually destroyed by the erysipelas cocci. One should, however, take into account that such an inoculation may cause death, and hence one should warn the patient of the danger of the treatment.

The man who succeeds in discovering a really successful method of treating malignant tumours—carcinomata, for example—would deserve to be honoured by humanity for all time as being its greatest benefactor.

§ 128. **The Different Varieties of Tumours.** *Connective-tissue Tu-*

mours; Fibroma.—Of the different varieties of connective-tissue tumours, we shall first take up the fibroma, which is made up almost entirely of this kind of tissue. We distinguish ordinarily a hard (Fig. 400) and a soft (Figs. 401, 402) form. The hard fibroma is made up, as a rule, of bundles of tough, coarse fibres with few cells, while the soft form consists of loose connective tissue having a great number of cells. There are, of course, numerous transition forms. The soft fibroma (fibroma molle) is also called fibroma molluscum by Virchow (Figs. 401, 402). The vascularity of the fibromata varies greatly, being sometimes very slight, and again so marked as to give rise to large dilatations of the blood and lymph vessels, as in the diffuse hyperplasia of tissue found in elephantiasis. Fibroma molluscum must not be confounded with the so-called molluscum contagiosum (see page 773).

Fig. 400.—Hard fibroma of the skin of the nose (Billroth).

The retrograde changes that take place in fibromata are fatty degeneration, calcification, softening, the formation of cavities and cysts, and a perforation of the skin with the formation of ulcers as a result of long-continued traumatic irritation from without, and of inflammation leading to the formation of abscesses. The fibroma only becomes dangerous from its location and size, the latter being sometimes very great, particularly in the case of fibroma of the skin or uterus (Fig. 402). In other respects the fibroma is a perfectly benign neoplasm, giving rise to no metastases, although it is found multiple, especially in the skin, where it may appear in vast numbers. The multiple fibromata of the skin (Fig. 402) may be the size of a pea or walnut, or they may grow and form very large soft tumors; they are sometimes accompanied by disturbances of the general nutrition (so-called leontiasis, Virchow). I cannot discuss here the question (see § 85) whether in such cases we do not really have to do with leprosy. According to the investigations of Recklinghausen, the multiple soft fibromata of the skin develop particularly from the connective-tissue sheaths of the sebaceous glands, vessels, and nerves (neuro-fibroma).

Fig. 401.—Soft fibroma of the face (elephantiasis faciei) of a twenty-four-year-old woman (Schüller, Greifswald clinic).

Many soft fibromata are diffuse, hyperplastic formations, and represent a transition to elephantiasis, as seen in Fig. 401. These formations are sometimes called cutis pendula or elephantiasis of the skin. There are also observed in some cases pigmentations which take the form of congenital moles, or of brown discolourations with a growth of hairs (see Angeioma, page 755). Many of the soft fibromata develop into angeiomata, cavernomata, and lymphangeiomata. Just as in the skin, there are also found in the internal organs diffuse fibromata, which in these structures likewise develop from the connective-tissue sheaths, especially of the glandular ducts and vessels; amongst these is the fibroma vegetans intercanaliculare mammæ.

Fig. 402.—Multiple soft fibromata of the skin (fibroma molluscum multiplex, Virchow) occurring on a forty-seven-year-old woman (Virchow).

Keloid.—In speaking of the hard fibromata, mention should be made of the keloid, i. e., a tumour-like, fibrous degeneration of the skin and subcutaneous tissue in the form of a tough swelling which sends out cord-like processes into the healthy surrounding parts. In by far the majority of cases the keloid develops within a cicatrix (cicatricial keloid). We distinguish, as do Warren, Kaposi, Denériaz, and others, three forms of keloid: (1) a spontaneous, (2) a cicatricial keloid, and (3) the hypertrophied cicatrix. Scrofulous, tubercular and syphilitic individuals seem especially prone to keloid. Denériaz is disposed to think that keloid is caused by infection with microbes. It is characteristic of keloid to recur almost invariably after extirpation. Leloir and Vidal recommend, in true keloid, multiple scarifications, which should be made in different directions during several sittings, and followed by the application of a moist dressing with compresses wet in boric-acid solution, and on the next day of a mercurial plaster.

Fibromata are most commonly found in the skin and subcutaneous

tissue, in the nerves, periosteum, bone, uterus, and ovaries. Some of the polyps which form in the facial cavities—many nasal polyps, for example—are periosteal fibromata. There are sometimes seen, especially n the pharynx, polyps which are covered with hairs and possess an epidermis, rete Malpighii, and corium, and, according to Arnold, originate from strayed embryonic cells. They belong, probably, to the teratomata (see page 787).

Combination or mixed fibrous tumours include fibro-myxoma, fibro-myoma, fibro-sarcoma, fibro-neuroma, fibro-angeioma, fibro-cavernoma, fibro-lymphangeioma.

The diagnosis of fibroma can be easily made from what we have stated in describing the neoplasm.

Treatment of Fibroma.—The treatment of a fibroma consists in its removal by the knife, the galvano-cautery or the thermo-cautery. Large diffuse fibromata of the skin are to be extirpated in several sittings by cuneiform excisions followed by deep sutures. Billroth once removed a large tumour in twenty sittings. I removed an extensive diffuse fibroma involving almost the entire scalp in one sitting, and covered the surface of the wound with Thiersch skin grafts. In cases of very large fibromata of the uterus one must often give up all idea of extirpation, and treat with injections of ergotine, or, in order to stop the frequent hæmorrhages, remove both ovaries (Hegar). The description of operations for fibroma of the uterus, etc., is found in the Special Surgery.

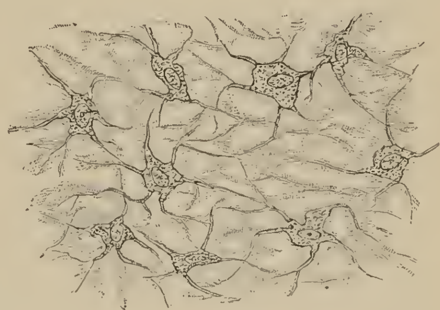


Fig. 403.—Cells from a myxoma of the cervical fascia. × 350.

Fibromata of nerves can usually be removed and the continuity of the nerve preserved (see Neuroma). If the nerve cannot be saved, the nerve stumps can sometimes be united after the extirpation of the tumour by suture, or by the use of the neuroplastic methods described on pages 470–472.

Myxoma.—The myxoma is made up of a soft, gelatinous tissue. The microscopic examination shows the presence of a mucoid ground substance with a fibrillår framework and round, spindle-shaped or star-shaped cells. The latter have usually many branches and processes which interlace with one another (Fig. 403). Köster has denied that the myxoma is a special form of tumour, and, as a matter of fact, it is possible to look upon it as in the main a softened, œdematous fibroma

or lipoma (myxo-fibroma, myxo-lipoma). Myxomatous, softened areas are often found in cartilaginous tumours.

The myxomata are met with most commonly in the skin and subcutaneous tissue, in the periosteum, medulla of bone, fasciæ, muscular sheaths, nerves, and in the brain and its coverings. They sometimes attain a very large size.

The treatment of a myxoma consists in its removal according to the above rules.

Lipoma.—The lipoma (fatty tumour) is a lobulated tumour made up of fatty tissue, sometimes soft and sometimes firm in consistency. The lipomata are either circumscribed or diffuse growths, and frequently possess a pedicle. According to their location, there may be distinguished cutaneous and subcutaneous, subserous (subperitoneal), subsynovial, submucous, inter- and intramuscular (subfascial, peritendinous) and periosteal lipomata. The lobes of fat of which the lipoma is made up are usually held together by bands of connective tissue. Increased development of the stroma gives rise to the lipoma fibrosum. In some instances, especially in the region of the neck and shoulder, very diffuse lipomata are found. Growth of the fatty villi in the joints, of which the knee is a prominent example, gives rise to the lipoma arborescens. Similar diffuse lipomata are found on the tendon sheaths. The articular lipomata probably develop as a result of traumatic ruptures of the synovial membrane, causing a prolapse of the retrosynovial fat into the joint; they are also encountered in arthritis deformans. The subperitoneal and submucous lipomata which develop upon the stomach and intestine are of special clinical importance. The lipomata of the intestine occasionally give rise to intestinal obstruction. According to Sutton, two forms of lipoma are found attached to the spinal cord. In most cases they are the result of the change of the sack of a spina bifida into fatty tissue; less frequently they are intradural lipomata which grow around the spinal cord. The lipomata, as we remarked before, sometimes change into fibromata, myxomata, sarcomata, and cavernous tumours. They may attain a considerable size, especially when situated on the back, and growths of this kind, weighing twenty to twenty-five pounds, have been successfully removed (Billroth, Hahn, and others). Pick published an account of a subserous lipoma of the abdomen weighing twenty-nine pounds. The lipoma is a benign tumour, and does not give rise to metastases, though it is sometimes multiple. They are most likely to develop in individuals from thirty to fifty years of age, but are sometimes congenital, in which case they are usually diffuse, often combined with teleangciectases, dermoid cysts, and fibromata, and occur principally in

the lumbar region and on the buttocks. The so-called "false tail" is merely a congenital lipoma pendulum which is situated above the anus, and may occasionally be combined with spina bifida (Bartels).

Quite recently Grosch has published the results of very exhaustive studies on this subject, which place the seemingly simple lipomata in a new light. He has attempted to show that certain tumours are prone to develop upon particular parts of the body, mainly on account of definite anatomical conditions and structural peculiarities which these parts possess. The lipomata appear to have a specially marked tendency to grow in certain localities, being most common on the front and back of the neck, on the posterior aspect of the trunk, about the shoulder, and on the upper and lower extremities. They are seldom encountered on the head, and then more often on the face than on the scalp, being rarest in the latter region (König, Gussenbauer). Grosch states that they occur most commonly in the integument of those parts of the body which have a scanty covering of hair and a small number of sweat and sebaceous glands. These glands eliminate fats and their derivatives in addition to disintegrated products of metabolism, and hence the amount of their secretion is an important index of the amount of the subcutaneous fat. Obesity and lipoma formation are, according to Grosch, quite identical. In many cases, particularly in thin individuals, the lipomata are neuropathic in nature, and possibly are the result of a diminution in the secretion of the sebaceous and sweat glands due to disturbances in the central nervous system. Symmetrical lipomata, in particular, result in this way.

The diagnosis of a lipoma is made chiefly from its soft, movable, lobulated character. If pressure is exerted upon the tumour, as a rule there will be felt a distinct crepitation caused by the crushing of single lobes of fat. The skin over the lipoma shows little shallow depressions which are particularly plain when the tumour is encircled by the hand.

The extirpation of lipomata by the knife and scissors is very easy even in the case of large tumours.

Fig. 404.—Small-celled chondroma of the finger. × 80.

Fig. 405.—Large-celled chondroma of the pelvis very rich in cells. × 80.

Chondroma or Enchondroma.—The chondroma consists essentially of cartilage, most commonly hyaline, less often fibrous or reticular. The

cells which this kind of tumour contains may be small (Fig. 404) or large (Fig. 405), and their quantity varies within wide limits. The enchondromata are most often encountered in places where cartilage normally exists — hence, upon the skeleton (epiphyses, periosteum, medulla of bones)—though they are also met with in the parotid and thyroid glands, mamma, and testicle. The enchondromata of the skin and internal organs develop partly from stray cartilage cells and partly from transformed connective-tissue cells, especially the endothelia of the connective-tissue sheaths and of the blood and lymph vessels. Thus chondro-endotheliomata are sometimes seen. The enchondromata which grow directly from cartilage—that of the epiphyseal line, for example—are also called ecchondroses. Like the exostoses, the enchondromata are often multiple, and appear in great numbers. Very remarkable cases of multiple enchondromata of different bones, combined with venous angeiomata of the soft parts, have been described by Kast, Recklinghausen, and others. Probably both kinds of tumours were the result of disturbances of circulation. Enchondromata are comparatively often the seat of degenerative changes, such as myxomatous softening and cyst formation. The most important mixed forms of chondroma are the osteochondroma and chondrosarcoma. Chondromata may eventually become entirely ossified. I have also seen a chondroma combined with a melanosarcoma—on the hand, for example. Not infrequently enchondromata are found multiple in different parts of the body. The simple enchondroma is in general a benign neoplasm, but malignant forms with metastases do occur. It is most often found in young subjects. The tumours attain at times a very considerable size, especially when situated upon the pelvis or the femur. A favourite locality for enchondromata is the fingers, where they form characteristic nodular tumours (see Fig. 406). They may also originate from cartilage cells in the ethmoid bone, and grow as an osteochondroma or cartilaginous exostosis into the frontal sinus and nasal cavity. These osteochondromata or exostoses of the frontal sinuses and nasal cavity can become detached, and are then found in these cavities in the form of free bodies or dead osteochondromata or osteomata. I once published a typical case of this kind. The frequency with which enchondromata or ossified chon-

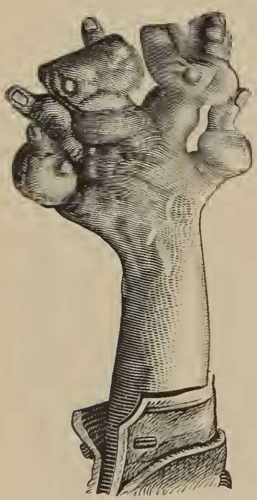


Fig. 406.—Enchondroma of the fingers of the left hand of a twenty-year-old spinner (Leo).

dromata (exostoses) of the ethmoid bone occur can be explained by the fact that remnants of the cartilaginous cranium remain in this locality for a comparatively long time.

The location and the hard nodular consistency of the tumours are important factors in making the diagnosis. The treatment consists in their prompt removal with the hammer and chisel.

Osteoma.—The osteoma is a tumour made up of bone, and occurs not only upon the skeleton, but also in the skin, muscles, tendons, lungs, parotid gland, and brain. We have already spoken of diffuse and circumscribed osteomata—the hyperostoses and osteophytes—in connection with inflammations of bone (see page 620), and of the so-called "riding" or "exercise" bones which develop in the muscles (see page 551), and of the diffuse formation of bone which takes place in myositis ossificans progressiva (see page 552). The development of bone in tissues where bone is usually not present is best explained by Cohnheim's theory—i. e., by supposing that strayed embryonic cartilage, periosteal or medullary cells have led to the production of osseous tissue. Osteomata also frequently appear upon bones after fractures. I once successfully removed such a one, almost as large as a fist, from the horizontal and descending ramus of the pubic bone, where it had followed a fracture.

The osteomata situated on the surface of bones are also called *exostoses* (Fig. 407), and those in the interior of bones *enostoses*. The exostoses which are developed in the periosteum are sometimes very movable, and do not have a direct connection with the bone. Their structure is in some cases as compact as ivory (osteoma eburneum), and in other cases spongy (osteoma spongiosum). Many osteomata have a covering of cartilage (exostosis cartilaginea), and this is especially true of the exostoses in the neighbourhood of the epiphyseal cartilage, which are really ossified enchondromata or ecchondroses (ecchondrosis ossificans). The cartilaginous exostoses (osteomata with a covering of hyaline cartilage) are sometimes styloid or finger-shaped, and resemble a metacarpal or metatarsal bone. These cartilaginous exostoses, or rather ossified chondromata, are often multiple, occurring in the neighbourhood of the epiphyses of many different bones in the same individual. Occasionally the influence of heredity is very noticeable. Hey-

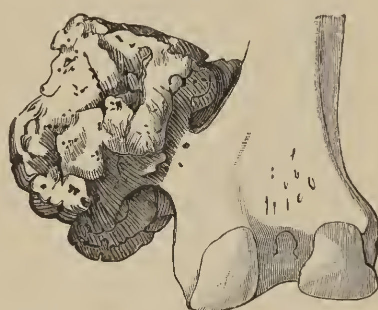


Fig. 407.—Exostosis of the femur (Busch).

mann observed multiple cartilaginous exostoses on many of the bones of a phthisical patient whose mother and four brothers, as well as his three children, all had a similar peculiarity. Reinecke collected thirty-six cases of multiple exostoses from literature, in which the hereditary predisposition could be traced back in one case five generations, in fifteen cases three generations, and in twelve cases two generations. In such instances the development of the exostoses is due to an inherited predisposition, and begins usually in the third or fourth year of life.

By *exostosis bursata* is meant an exostosis which is covered by a bursa. It develops principally in the joints, from the articular cartilage, and pushes the synovial membrane before it. The pocket thus made in the capsule of the joint either remains open, so that the bursa retains its connection with the joint, or it becomes entirely cut off from the latter (see page 690).

These bursal or synovial exostoses generally contain a fluid resembling synovia, and several free-joint bodies usually made up of hyaline cartilage. This form of exostosis may also occur at some distance from a joint, and even upon the bones of the trunk and ribs; in these cases the enveloping sack forms, after the fashion of an accessory, mucous bursa. The exostoses can become gradually or suddenly detached by traumatisms, for example, and then persist as dead pieces of bone, like the free dead osteomata in the frontal sinuses and nasal cavity.

Osteomata of the teeth and alveolar processes are comparatively common. The tumours of the teeth, the so-called odontomata, which consist of dentine and enamel, arise from the pulp or degenerated embryonic tooth cells as a result of anomalies during the period of development of the teeth, and sometimes in young subjects after injuries. The true odontomata are rare, and are found, according to Heath, almost exclusively on the lower jaw. Lloyd saw an odontoma of the upper jaw, and Metnitz has published an account of five cases of this rare form of tumour, and thinks that want of room, abnormal position of the neighbouring teeth, and inflammatory processes, especially chronic periostitis, are important factors in their etiology. In general, two forms of odontoma can be distinguished—soft and hard—or, better, those with dentine and those without (Partsch). The exostoses which form on teeth are, of course, not to be counted amongst the odontomata, but amongst the osteomata.

The osteömata are, on the whole, benign tumours, and usually grow slowly, but sometimes are found multiple, occurring, for example, on numerous epiphyses, where they are capable of causing disturbances of growth. In cases of multiple exostoses of the bones of the cranium

and face, atrophy of the latter has been observed as a result of interference with its development. The malignant osteomata include the osteosarcoma, also called osteoids (see Fig. 408), which give rise to extensive local destruction of tissue and to metastases (see sarcoma). In this category belongs also the very vascular (pulsating) osteosarcoma. For cysts of bone see page 785.

Fig. 408.—Osteosarcoma (osteoid, malignant exostosis) of the superior maxilla (Busch).

Pointed exostoses can sometimes cause injuries to large arteries and veins, and thus lead to the formation of aneurysms, as in the instances observed by Boling, Küster, and others. In Küster's case a pointed osteophyte wounded the popliteal artery and led to the formation of an aneurysm. After removal of the osteophyte by a chisel, and double ligation of the popliteal artery, a rapid recovery was made. Krönlein observed, on the other hand, that a traumatic aneurysm of the popliteal artery which had lasted ten years caused an erosion and formation of osteophytes on the lower end of the femur.

The diagnosis of osteomata can usually be made from their location and hard, bony consistency.

Osteomata are usually removed by the chisel or saw, or when in the soft parts, by extirpation with the knife. In cases of exostoses in the vicinity of a joint one should always think of the possibility of their communicating with the joint. In such cases the tumour is only removed when it causes serious trouble.

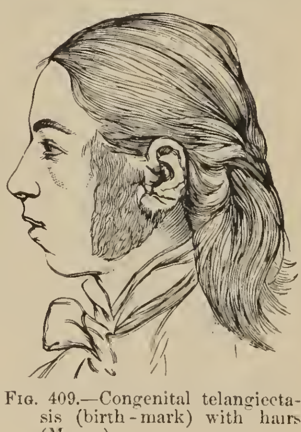


Fig. 409.—Congenital telangiectasis (birth-mark) with hairs (Mason).

Angeioma (*Blood-vessel Tumour*).—The *angeioma* is made up principally of newly formed and old, dilated, hypertrophied blood-vessels. Three varieties are distinguished :

1. *The angeioma simplex* (teleangeiectasis, nævus vasculosus, plexiform angeioma), consists of dilated, tortuous, and newly formed capillaries and small vessels. Macroscopically, the teleangeiectases are mostly soft swellings, bright- to dark-red in colour, which are only slightly elevated above the surface of the skin, where they are usually found. They are very

often congenital, forming the so-called birth-mark. These birth-marks are often associated with hypertrophy and pigmentation of the skin, and very frequently with hair-formation (see Figs. 409 and 411). Many of these hairy birth-marks are diffuse, soft fibromata, others more like teleangeiectases. The hair-formation often resembles the hide of animals, such as rats, monkeys, or rabbits. The mothers of such children often say—as in the cases illustrated in Figs. 409, 410—that they were frightened during pregnancy by the sudden appearance of the animal whose skin resembles that of the birth-mark. The marked heteroplastic development of hair on certain parts of the body which are covered with an otherwise normal skin—the growth of a beard in women, for example (hypertrichosis circumscripta)—and the growth of hair over the entire body (hypertrichosis universalis), have nothing to do with tumour-formation; it is mostly a hereditary malformation which is found in certain families. Several families of hairy people are known in which the complete covering of the body with hair was inherited by the children. Fig. 411 represents Schwe-Maong, the father of an Asiatic hairy family, and Fig. 412 the Russian hairy man Andrian, whose son had the same peculiarity. Treatment by the galvano-cautery may be used for this abnormity.

Fig. 410.—Very large congenital hairy birth-mark on the back, neck, and upper extremity of a twelve-year-old girl (Beigel and Paget).

The angeiomata also include the aneurysma anastomoticum or racemosum, which is best called angeioma arteriale racemosum or cirsoid aneurysm, and has been described in a previous chapter (Fig. 413). The cirsoid aneurysm, as we saw on page 535, is the result of a pampiniform dilatation, tortuosity, and thickening of the arteries supplying a certain region,

Fig. 411.—Shwe-Maong, ancestor of an Asiatic hairy-family.

Fig. 412.—Andrian, a Russian hairy man (Virchow and Bartels).

and is due partly to the formation of new vessels and partly to hypertrophy of the old ones.

2. The *cavernous angeioma* (tumor cavernosus) resembles in structure the corpus cavernosum—i. e., it consists of cavities lined with endothelium, which are filled with fluid or coagulated blood, and separated by connective-tissue septa. It is most commonly found in old people in the liver, skin, subcutaneous tissue; less often in the brain, spleen, kidneys, uterus, or bone. The views as to its origin do not agree. According to Rokitanski, the cavernous spaces are first formed from the connective tissue, and then secondarily become joined with the blood-vessels and thus filled with blood. Another explanation seems to me the more probable—viz., that a dilatation of the capillaries first takes place, and subsequently the walls of the dilated capillaries which lie next one another gradually disappear, resulting in the formation of large cavities filled with blood.

Fig. 413.—Angeioma arteriale racemosum (cirsoid aneurysm) of the art. angularis and frontalis dextra et sinistra of a twenty-year-old man (Bruns). Ligation of the right external carotid and left common carotid. Death due to cerebral embolism.

Angeioma is not infrequently combined with fibroma, lipoma, and sarcoma (angeiosarcoma).

The treatment of angeiomata consists in their extirpation with the knife, if possible, or with the galvano-cautery or thermo-cautery (so-called ignipuncture or punctiform ustion). In order to operate without loss of blood, the base of the angeioma may in appropriate cases be transfixed and tied off in two or more parts, or portions of the tumour may be seized by clamps before they are divided. Large, diffuse angeiomata, like cirsoid aneurysms, may, if removal is impossible, be treated by ligation of the afferent arteries combined with ignipuncture. Cirsoid aneurysm occurs most commonly on the scalp, and in this situation might require ligation of the external carotid. If the main artery is too short, each of its branches should be secured. It is dan-

gerous to ligate the common carotid on account of the changes which may thus be produced in the cerebral circulation. For the purpose of preventing recurrences it is often advisable to apply to the diseased part for a considerable time dressings which exert pressure or to paint it with iodoform collodion. Amongst other methods which have been recommended are electrolysis, parenchymatous injections of the tincture of iron, liquor ferri (Monsell's solution), absolute alcohol, liquor Piazza (sodii chlor. 15·0 grammes; liq. ferri sesquichlorati [thirty per cent.], 20·0 cubic centimetres; aq. destil, 60·0 cubic centimetres [St. Germain]). Great care should be taken not to make the injection into healthy subcutaneous tissue. Gunn and Haven speak well of the injection of carbolic acid (ninety-five per cent. acid. carbol. and glycerine, āā) into the peripheral parts of the angeioma (a few drops in from five to fourteen different places). Setons made of threads saturated in liquor ferri, and then dried and passed through the growth, used to be employed, as were also the ligature (see page 72), cauterisation with fuming nitric acid, etc. These are all methods of treatment which have now become obsolete.

Lymphangeioma (*Angeioma Lymphaticum*, *Lymphangeiectasis*).—The lymphangeioma corresponds to the angeioma of the blood-vessels, and consists essentially of dilated and hypertrophied lymph vessels (Fig. 414). The following varieties may be distinguished: 1, lymphangeioma simplex (teleangeiectasia lymphatica); 2, cavernous (lymphangeioma cavernosum [Fig. 414]); and 3, cystic lymphangeioma (lymphangeioma cysticum). Some lymphangeiectases are acquired and others are congenital. The great majority of lymphangeiomata are probably due to disturbances of embryonic development; a simple lymph stasis would not be sufficient to explain them, although it can favour the growth of a lymphangeioma which already exists. They usually communicate directly with the lymph vessels, and in one case Nasse was able to demonstrate an open connection between a cavernous lymphangeioma of the neck and the subclavian vein and thoracic duct—a circumstance which can only be

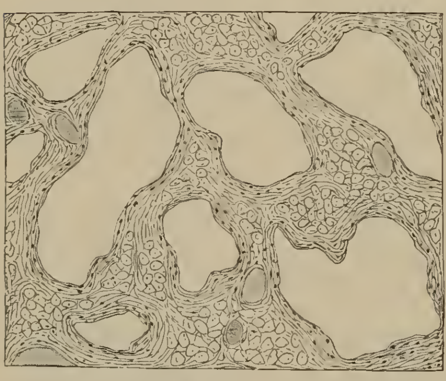


Fig. 414.—Lymphangeioma cavernosum of the subcutaneous cellular tissue of the neck, consisting of enlarged lymph vessels with hypertrophic walls. × 30.

explained on the grounds of a disturbance of embryonic development, as mentioned above.

In consequence of this communication of a lymphangeioma with veins caused by abnormities in fœtal development, large blood-cysts are formed, especially on the neck (Bayer). The congenital lymphangeiectatic hypertrophy of the tongue (macroglossia) and of the lips (macrocheilia) belong to the congenital lymphangeiomata. Lymphangeiomata sometimes reach a very considerable size. The fluid which they contain is, as a rule, clear, but sometimes milky. If one bursts, a lymphorrhœa or lymph fistula results, through which large amounts of this fluid may escape (see page 543). Lymphangeiectases are very often found in connection with the diffuse hyperplasia of connective tissue forming the so-called elephantiasis (elephantiasis lymphangeiectatica, see page 523).

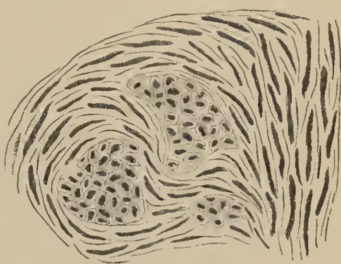


Fig. 415.—Leiomyoma of the uterus; some of the nuclei of the muscle fibres have been cut longitudinally, and others transversely. × 200.

The treatment of lymphangeioma has already been spoken of. When possible, it consists in extirpation of the growth—a procedure which is sometimes very difficult. Simple incision and drainage, or packing with iodoform gauze, may prove effective in cystic tumours; but this method should not be used when numerous small cavities are present. Bergmann has obtained very good results from extirpation, and Rehn successfully removed a lymphangeioma cavernosum of the sacral canal which pressed upon the cauda equina.

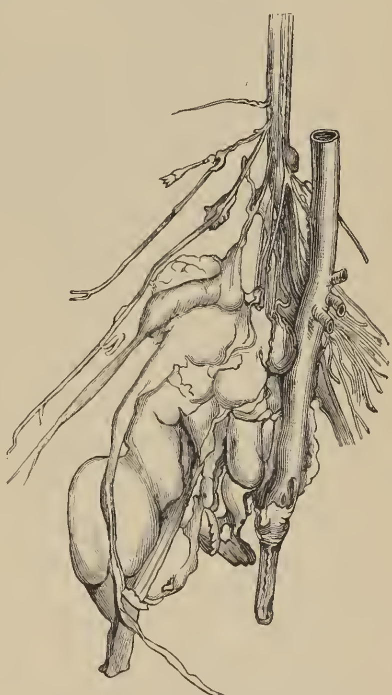


Fig. 416.—Plexiform neuroma of the lumbar plexus (Czerny).

Myoma (*Muscle Tumour*).—The *myoma* is made up essentially of muscle fibres, which may be either striated (rhabdomyoma, myoma strio-cellulare) or non-striated

(leiomyoma, myoma lævicellulare, Fig. 415). Simple rhabdomyomata are very rare, the myosarcoma being the most common tumour of striated muscle. Striated muscle fibres and spindle cells with striations are often seen in sarcomata of the testicle, kidney, and in tumours of the ovary (myosarcoma). Probably in such cases strayed embryonic muscle cells have become deposited in these organs. The leiomyoma is most common in the uterus and intestinal tract, where it takes the form of nodular tumours, which are more or less pure myomata or fibro-myomata. Microscopically, the non-striated muscle fibres are recognised on longitudinal section by the rod-like nuclei and their regular arrangement. On cross section the characteristic contours of the fibres are seen, together with the transverse section of the nuclei, in their interior (Fig. 415). The leiomyomata of the uterus often take on secondary changes, such as extensive fatty degeneration, calcification, cyst formation, and suppuration. They are occasionally combined with sarcoma and carcinoma.

Fig. 417.—Plexiform neuroma of the lower part of the face and neck on the right side in a boy ten years old (Bruns).

The treatment of myomata of the uterus, for example, is in the main the same as that of fibroma (see page 749).

Neuroma (*Nerve-fibre Tumour*).—The *neuroma* is made up essentially of newly formed nerve fibres. A distinction is made between true and false neuroma. Most neuromata are false—that is, they are fibromata or myxomata of the connective-tissue portion of nerves, with displacement and atrophy of the nerve fibres. They generally form flask-like swellings of the nerves, or cylindrical or spherical tumours, about the size of a bean, cherry, or plum, and, in rare cases, the size of

a hen's egg. The false neuromata are often multiple. Bergmann, for instance, observed more than a hundred neuro-fibromata of the skin in a man fifty-four years old. The so-called amputation-neuromata, which are club-shaped swellings of the ends of the nerves in amputation-stumps, are, as a rule, made up mostly of newly formed connective tissue, with more or less numerous collections of newly formed nerve fibres. The so-called plexiform neuroma also belongs to the false neuromata or fibro-neuromata. It is essentially a nodular, fibrous degeneration of the branches of a particular nerve, the trunk of which becomes twisted and tortuous (Figs. 416, 419). These plexiform neuromata, of which the rudiments were present in the embryo, are very much like soft fibromata of the skin and subcutaneous cellular tissue, in which they form flabby, lobulated folds and elevations (Fig. 417), sometimes uneven and nodulated, usually containing dark pigment and covered with hair, as in elephantiasis (Fig. 401). Very large tumours sometimes result from this elephantiasis-like hyperplasia of the skin and subcutaneous tissue. The plexiform neuroma is, according to Bruns, almost always situated in the subcutaneous tissue, and only exceptionally in the deeper parts, as in a case seen by Pomorski, in which a plexiform neuroma of the intercostal nerves had grown into the pleura. Bruns collected from literature a large number of instances of plexiform neuroma, and found that its most common location is on the temples and upper eyelid (fifteen cases). It was found eight times in that part of the neck which lies posterior to the ears, three times on the nose and cheek, four times near the lower jaw and front of the neck, seven times on the breast and back, and three times on the extremities.

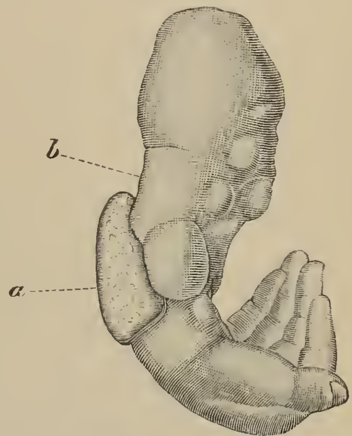


FIG. 418.—Neuroma amyelinicum multiplex recurrens ulcerosum antibrachii. Most of the nodules lie beneath the skin: *a*, ulcerating nodule; *b*, scar from a previous extirpation of the primary neuroma (Virchow).

The *true* neuromata consist for the most part of newly formed nerve fibres, which develop in one or more peripheral nerves. Some cases of amputation neuromata also belong to this class of tumours. Depending upon whether the neuroma is made up of medullated or non-medullated nerve fibres, we make a distinction, as Virchow does, between a neuroma myelinicum and a neuroma amyelinicum. The brain and certain neoplasms of the testicle and ovary are sometimes the

seat of a cellular (ganglionic) neuroma. The neuroma is in general a benign tumour, though it is sometimes multiple in the nerves of the brain and spinal cord.

In rare cases neuromata are found to be malignant, giving rise to local recurrences after extirpation, and even to metastases (Fig. 418). Benign neuromata can sometimes rapidly become malignant by changing into sarcoma. Krause has collected from literature twenty-four such cases. Microscopically, the malignant neuromata are usually myxomata or lipomatous myxomata, or medullary, round, or spindle-

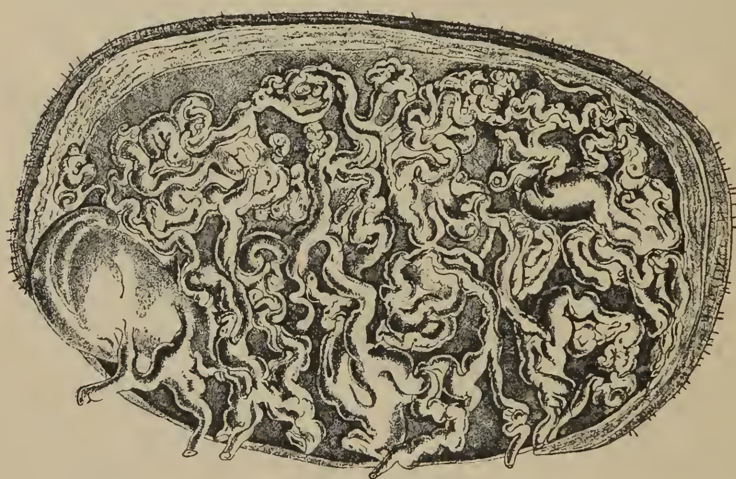


Fig. 419.—Plexiform neuroma; specimen taken from the case illustrated in Fig. 417 (Bruns).

celled sarcomata, or coarse fibrous neuromata, which nevertheless run a very malignant course. Softening and cyst formation in the centre of the tumour are common. The malignant neuromata usually spring, according to Krause, from the nerve sheaths, especially the intra-fascicular tissue. They can develop rapidly to tumours the size of a man's head, and are especially common on the large nerves of the extremities, such as the median and great sciatic, but are not infrequently met with in the small cutaneous nerves. Newly formed medullated nerve fibres are occasionally found in the neuromata—a fact which is not remarkable, as we know that degeneration and regeneration of nerve fibres take place in normal nerves.

The so-called tubercula dolorosa, which appear as small, movable, painful, subcutaneous tumours, are, according to Virchow, in some instances true neuromata, while in others it has not been possible to demonstrate nerve fibres.

As regards the treatment of neuroma, I may say that neuro-fibromata and neuro-myxomata can usually be removed and the continuity of the nerve be preserved. If extirpation is not possible, as in the case of large nerves of the extremities, for example, and the removal of the tumour is indicated on account of great pain, rapid growth, etc., the continuity of the nerve must be restored, after the extirpation of the neuroma, by means of sutures or a plastic operation. The treatment of a plexiform neuroma, which involves the whole region of distribution of a nerve, is merely palliative in case an extirpation is impossible. The treatment of amputation neuromata was described on page 126.

Glioma.—Gliomata occur especially in the brain, less often in the spinal cord, and result from the growth of the neuroglia cells of the central nervous system. They form pale-grey, greyish-white, or, when very vascular, reddish or dark-red tumours, which are usually not sharply defined. They are not infrequently the seat of retrograde metamorphoses, such as fatty degeneration, caseation, and softening. Under the microscope the gliomata are seen to be made up of a network of fine, translucent fibres, which contain branching cells resembling those of the neuroglia. According to Klebs, Heller, and others, many gliomata consist of growing ganglionic cells and newly formed nerve fibres. Ziegler is right in separating these from the gliomata, and calls them neuroglioma ganglionare.

Lymphoma.—By lymphoma we understand a true neoplasm as well as a chronic inflammatory or infectious hypertrophy of lymph glands. The latter may originate as a result of local and constitutional causes. In this category belong, for example, the lymphomata of the neck following chronic inflammation of the skin or mucous membrane in the region supplied by the lymphatic vessels which lead to the enlarged glands, also the lymphomata due to local or general tuberculosis, or which occur in the course of leucæmia, and the progressive lymphomatous formations encountered in anomalies of the organs producing the blood (malignant lymphoma, Hodgkin's disease, pseudo-leucæmia). The word lymphoma signifies, in general, hyperplasia of lymph glands, but if the enlargement is caused by a true neoplasm, we call it, according to its structure, a lympho-sarcoma, lympho-adenoma, etc. The above-mentioned progressive formation of lymphomata, the so-called malignant lymphoma, is exceedingly interesting. The disease usually begins with a large, nodular swelling of the lymph glands of the neck (see Fig. 420) which is entirely free from pain. As a rule, the nearest lymph glands become successively swollen, then the glands of the other side, and, finally, in many cases the mediastinal and the retroperitoneal glands. The microscope shows a simple hyperplasia of the lymph

glands, though Goldmann observed in them a marked increase in the number of cells which can be readily stained by eosin (eosinophilous cells). Metastases in the internal organs are of frequent occurrence (lungs, spleen, liver, kidneys, bone), and the enlargement of the spleen may become very marked. The general health can remain undisturbed for a comparatively long time, but ordinarily a steadily increasing loss of flesh and strength soon sets in and is followed by death. Occasionally, as in goitre, the end comes suddenly from suffocation in consequence of softening of the laryngeal cartilages or of paralysis of the vocal cords due to bilateral pressure on the recurrent nerve. The etiology of malignant lymphoma has not been thoroughly investigated. The white blood-corpuscles are not increased in numbers as in leucæmic lymphoma, hence the name pseudo-leucæmia. Malignant lymphoma or pseudo-leucæmia is probably the result of some as yet unknown infection.

FIG. 420.—Soft malignant lymphoma of the cervical glands of a boy eight years old (Winiwarter).

The treatment of lymphoma varies according to its cause. Neoplasms of the lymph glands should be extirpated as soon as possible. Tubercular lymphomata should also be treated in the same way, or scraped out with the sharp spoon, or treated by ignipuncture with the galvano-cautery, or parenchymatous injections of ten-per-cent. iodoform oil or iodoform glycerine, etc. I also excise simple, non-tubercular, so-called scrofulous hypertrophies in case they do not disappear under a general tonic regimen, a thing which is of great importance in the management of all lymphomata. The arsenic treatment is sometimes successful, both internally and in the form of parenchymatous injections. Billroth begins with ten drops of Fowler's solution *pro die* internally, and injects at first two, subsequently four to six drops a day into the substance of the tumour. The internal dosage may be raised two drops every third day, but if symptoms of poisoning make their appearance the doses must be diminished. A cure is not obtained in this way, but the patient improves and the course of the disease is checked or rendered less severe. The operative removal of malignant lymphomata is probably always unsuccessful, as recurrences appear, as a rule, very promptly. But they should be removed sufficiently to relieve at least the urgent symptoms, such as those caused by obstruction to respiration.

Sarcoma.—The sarcoma (Figs. 421, 422) is a neoplasm which springs from connective tissue, and is formed, in general, after the type of embryonic connective tissue with abnormal and luxuriant cell forma-

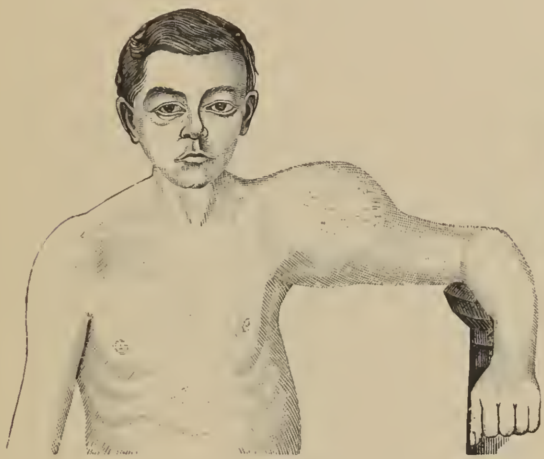


Fig. 421.—Sarcoma (osteo-sarcoma) of the left (upper) arm (Esmarch).

Fig. 422.—Sarcoma (myxo-sarcoma) of the dura mater in a twenty-eight-year-old man (Heineke).

tion. The sarcomata originate in all varieties of connective tissue (cartilage, bone, periosteum, ordinary connective tissue, fat tissue, etc.), and are particularly likely to start from the cells of the walls of the blood-vessels. Benign tumours, as we remarked before, not infrequently

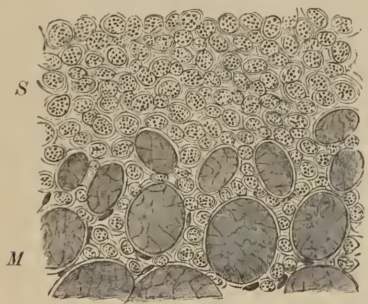


Fig. 423.—Marginal portion of an intermuscular sarcoma of the arm: *S*, sarcoma tissue consisting of round cells; *M*, transversely divided muscular tissue.

Fig. 424.—Portion of a sarcoma of the fascia of the thigh containing cells of various shapes (small and large round cells, spindle cells, polynucleated giant cells, etc.). × 250.

become sarcomatous, thus giving rise to mixed tumours, such as fibro-sarcoma, myxo-sarcoma, osteo-sarcoma, etc. Sarcomata in the skin, periosteum and marrow of bone occasionally appear in a multiple form.

The size and shape of the cells in a sarcoma vary within wide limits (Figs. 423–428), many being round cells, which are often contractile, like white blood-corpuscles, while others are spindle cells, endothelial cells, stellate cells, or giant cells. Between each of these there are numerous intermediate cell forms, and different shaped cells are often

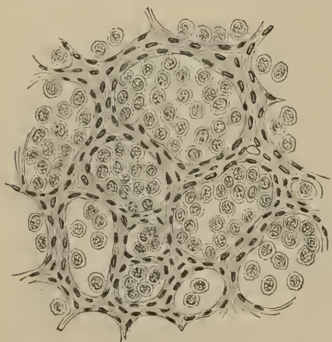


Fig. 425.—Small-celled alveolar sarcoma of the lymph glands of the neck. The alveoli between the connective tissue bands are filled with sarcomatous round cells. × 150.

Fig. 426.—Giant-celled sarcoma of the breast. × 300.

found lying next one another. There is a greater or less amount of intercellular substance which may be fibrous, homogeneous, reticulated, granular, mucoid, etc. The vascularity of sarcomata also varies very much, being occasionally so marked that the tumours pulsate like aneurysms. They likewise show great differences in consistency and colour. The very malignant, soft, rapidly growing sarcomata, made up largely of cells, are especially to be dreaded (medullary sarcoma). The pigmented varieties, the melano-sarcomata, are also very malignant. The formation of metastases takes place, as Billroth showed, principally through the veins, and to a less extent through the lymphatics. I once found in a case of medullary sarcoma of the lower extremity a metastatic deposit the size of a small pea in a valve of the femoral vein. The retrograde metamorphoses which take place are fatty degeneration, caseation, softening, cyst formation, hæmorrhage, and, after the disease has broken through the skin, ulceration and sloughing.

Sarcoma of bone originates either from the periosteum or from the medullary cavity. The latter, or myelogenic sarcoma, is characterised by having a greater number of giant cells. As long as the central (myelogenic) sarcoma of bone possesses a closed capsule the prognosis is favourable, but otherwise it is extremely bad. Out of twelve patients with sarcomata of the long bones which were removed with the knife, six died from recurrences, which in two of the remaining six

cases soon afterwards necessitated secondary operations. According to the shape of the cells and the structure of the sarcoma the following different forms are distinguished, which of course often merge into and combine with one another to a greater or less extent :

1. The *round-celled* variety occurs as the small- and large-celled sarcoma. The small round-celled sarcoma (Fig. 423) is made up of cells which resemble white blood-corpuscles, and as a rule grows rapidly, forming a soft tumour, which on section appears white, and when squeezed gives out a milky fluid. It consists of round cells, blood-vessels, and generally of a very small amount of a fibrous, granular, or homogeneous stroma. In some cases it has a pronounced alveolar structure, and then resembles gland tissue or carcinoma—i. e., the cells, or rather groups of cells, are divided off by connective-tissue septa (alveolar sarcoma, Fig. 425). The small round-celled sarcomata are usually very malignant in character; they destroy the surrounding tissues, forming metastases and running a course similar to carcinoma (§ 129). The most common locations for this sarcoma are connective tissue, muscle, fascia, periosteum, bone, lymph glands, etc.

The *large round-celled sarcoma* (Fig. 426), although it is not quite so malignant as the small-celled and does not grow as rapidly, is very similar to the latter in its clinical course. It also occasionally possesses an alveolar structure.

2. The *spindle-celled sarcoma* usually consists of cells which are for the most part long, thin, and spindle-shaped, lying close together (Fig. 427), with or without a variable amount of homogeneous or fibrous intercellular substance. If the latter is fibrous and abundant, the tumour is called a fibro-sarcoma.

Fig. 427.—Cells from a spindle-celled sarcoma of the thigh. × 300.

Fig. 428.—Cells from a myelogenic giant-celled sarcoma of the lower jaw. × 300.

3. The *giant-celled sarcoma* is characterised by the presence of a great number of very large, polynuclear, round, or polymorphous cells (Fig. 428), and originates most commonly in bone marrow (myelogenic osteo-sarcoma). Giant cells are also occasionally found in the round and spindle-celled sarcomata, but not by any means in such quantities as in the true giant-celled neoplasm.

4. *Stellate or reticular-celled sarcomata* are most commonly encountered in myxomata and myxo-chondromata which are combined with sarcoma. The stellate or reticular cells, with their interlocking processes, are usually embedded in a soft, gelatinous, mucoid intermediary substance.

5. In many sarcomata cells of all varieties of shapes are found together (sarcoma with polymorphous cells, Fig. 424).

6. The *alveolar sarcoma* (Fig. 425) which was mentioned above is made up of mononuclear and polynuclear cells, as a rule about as large as average-sized pavement epithelial cells, which lie singly or in groups in a fibrous, less often in a homogeneous intermediary substance. A characteristic feature of this variety is that the cells, contrary to carcinoma, are closely united to the connective-tissue stroma, and cannot be easily separated from the fibrous meshes. Although this forms the means of distinguishing the alveolar sarcoma from carcinoma, yet sections of the two tumours under the microscope often present such similar pictures that it is very difficult to recognise one from the other.

7. The *plexiform angeio-sarcoma* (Waldeyer) is to be looked upon as an angeioma with a sarcomatous growth of the walls of the vessels; it originates mainly by growth of the endothelial cells which lie next the adventitia of both the lymph and blood-vessels (Fig. 429). These cell growths surround the walls of the vessels like a sheath, and, as a growth of the inner endothelial cells also takes place, the lumen of the blood or lymph vessel in question may finally become entirely occluded. The reticulated anastomosing filaments and tubules of the cells usually lie in fibrillar connective tissue, and as a result of hyaline degeneration of the walls of the vessel hyaline tubules are formed having cells in their interiors, or the latter are so narrowed by the hyaline degeneration that only hyaline branching cords, bulbs, or spherules without cells are found. Occasionally the hyaline degeneration attacks primarily the cells in the tubules, so that the hyaline cords are surrounded by cells which have not yet become degenerated. The plexiform angio-sarcoma is really an endotheliosarcoma or endothelioma, and on account of the hyaline cylinders this tumour was once called a cylindroma. The endothelioma arises in some cases from the endothelium of the blood-vessels, and in others from the endothelioma of the lymphatics or connective tissue. Küster rightly called attention to the fact that there are hæmorrhagic sarcomata or angeio-sarcomata (endotheliomata) which show extensive degeneration of the walls of vessels —i. e., growth of endothelial cells and hyaline degeneration—before a tumour nodule has become developed; they lead to hæmatomata without macroscopically visible sarcoma tissue. In other cases such hæmatomata are followed, months after, perhaps, by remarkably malignant sarcomata. The plexiform angeiosarcoma or endothelioma is anatomically easily mistaken for carcinoma, and runs a similar course—i. e., it is a markedly malignant tumour,

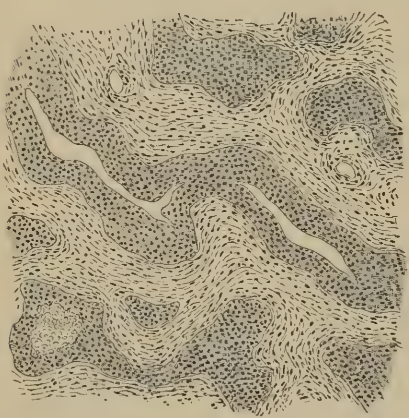


FIG. 429.—Plexiform angeio-sarcoma, or rather, endothelioma, of the thigh. The anastomosing groups of cells are derived in this instance from proliferation of the endothelium of the lymph vessels; they surround the latter like a sheath. In some places the groups of cells, or rather endothelium, are in solid masses, while in others they have undergone degeneration. × 30.

recurs after extirpation, and causes at a comparatively early period an infection of the nearest lymph glands and metastases. Hence some authors have designated the malignant endothelioma as endothelial cancer. Some of the endotheliomata should, however, not be counted among true neoplasms on account of their diffuse development, but should rather be assigned to the infectious tumours.

The *xanthoma* or xanthelasma, a sulphur-yellow or brownish-yellow pigmentation of the skin, is, according to De Vincentiis, Touton and others, an endothelioma in which fat has been deposited (endothelioma lipomatodes); it grows from the endothelium of the lymphatic vessels, and occurs in a flat (xanthoma planum) and nodular (xanthoma tuberosum) form, especially on the eyelids, though occasionally it has a multiple character, appearing on different parts of the body, particularly where there are folds of skin (flexor side of joints, axilla, neck, etc.). Now and then the eruption occurs more or less suddenly—in the course of diabetes, for example (xanthoma diabeticum) —at other times symmetrically, probably from tropho-neurotic disturbances. Occasionally it changes into sarcoma or fibroma (sarco-xanthoma, fibroxanthoma).

The villous sarcoma, the so-called cholesteatoma, which may be encountered on the meninges of the brain, probably owes its origin likewise to growth of the endothelial cells of the vessels, or rather of the cells of their sheaths.

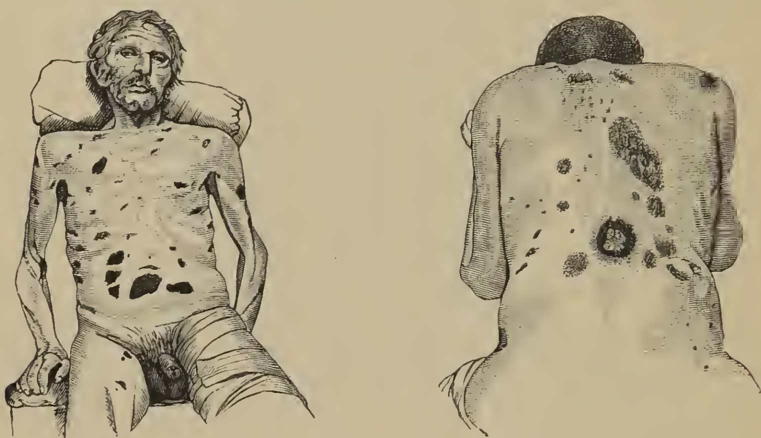
Perhaps the psammoma of the brain and orbit described by Virchow also belongs to the endotheliomata. They are characterised by the presence of large amounts of lime concretions similar to the "brain sand" normally present in the hypophysis cerebri. Such concretions are met with in sarcoma, fibroma, and myxoma, and, according to Billroth, are to be regarded as calcified bundles of endothelial cells which are attached to the blood-vessels, though Virchow thinks they are also the result of the calcification of connective tissue.

The melanosarcoma (pigmented sarcoma) is characterised by the presence of a brown or black pigment which is almost always deposited in the cells, less often in the intercellular substance and walls of the vessels. On section the melanomata are brown, or, if the pigmentation is excessive, black in colour. They are among the most malignant tumours, their growth being sometimes very rapid and the number of metastases considerable (see Fig. 430). They are most likely to develop in places where pigment is already present—as in freckles or pigmented warts, for example (Fig. 430)—and most commonly begin on the extremities. The origin of the pigment is doubtful. According to Gussenbauer, it is formed from the red blood-corpuscles of the thrombosed vessels, while others think that it is not identical with the pigment resulting from hæmorrhages, but may be due to a special activity of the cells (Birch-Hirschfeld). Schmidt considers the pigment to be hæmatogenous in nature, having passed the hæmosiderin stage and parted with its iron reaction.

Terrillon observed, in a case of melanosis which ran a rapidly fatal course, an increase in the number of white corpuscles in the blood and a large number of "black bodies." Melanuria is encountered in rare instances of multiple melanoma, and Zeller found variable amounts of hydrobilirubin and

melanin in the dark-brown but otherwise perfectly clear urine. The urine in melanosis, when first passed, is clear, but if allowed to stand becomes black, and at times almost the colour of ink.

The question of the transmissibility of melanoma, which has been experimentally studied by Lanz, has not yet been definitely settled, but I, person-



a b

Fig. 430.—Melanoma of the skin (man seventy-four years old) originating in a pigmented wart upon the back; within six months over one hundred pigmented spots and tumors formed upon the skin. Numerous melanosarcomata of the pleura, lungs, pericardium, liver, kidneys, and retroperitoneal glands were found (Lücke).

ally, do not doubt that it, like sarcoma and carcinoma, is capable of developing from inoculation, as shown by the following remarkable instance of this which was observed by Lanz: The latter injected into a guinea-pig a certain amount of an infusion of melanotic cutaneous nodules, melanotic brain, liver, and spleen. The animal died a month and a half after the injection, and the autopsy showed collections of pigment in many different parts of the body (skin, subcutaneous tissue, muscles, peritoneum, spleen, liver, kidneys, etc.). In this case the pigment must have been formed within the body, as only very little of the colouring matter was injected.

The chloroma is a pale, grass, or brownish green round-celled sarcoma, which, according to the observations that have been made up to the present time, originates in the periosteum of the bones of the face and cranium, and gives rise to metastatic green nodules in various organs, especially the liver and kidneys. According to Huber, the green colour is due to small, very refractive granules, which are found in the cells and which give the microchemical reaction of fat. The chloroma is also characterised by the presence of an abnormally large amount of chlorine.

We have already dwelt sufficiently upon the course and prognosis of sarcoma when discussing its different varieties. The duration of the disease depends in general upon the importance of the organ involved. The sarcoma of the brain is the most rapidly fatal, and may

cause death in one and a half to two months. Sarcomata of the mediastinum are likewise very malignant, and may prove fatal in a few months by suffocation or paralysis of the heart. The prognosis is most favourable in the sarcomata of the skin, which can be easily extirpated, and of the extremities in case the tumours are removed early enough by operative means. We have already mentioned that sarcoma, especially of the skin, can be made to disappear permanently by the inoculation of erysipelas. Among important diagnostic factors, besides the above-described general characteristics of sarcoma, are its location and the age of the patient. Its favourite location is in muscle, periosteum, bone, nerves, glands (lymph glands, parotid, testicle, mamma), and it not infrequently develops after an injury. As regards age, sarcoma is most common in middle life, and less so in childhood and old age. It is usually a painless tumour.

The general rule for treatment is to remove the neoplasm as soon as possible. In suitable cases of encapsulated, myelogenic giant-celled sarcoma of bone the anterior half only of the bony capsule may be removed by means of the hammer and chisel or the saw, and the tumour carefully scraped out with a sharp spoon. In inoperable cases the inoculation of erysipelas may be tried. Burns has observed three permanent cures in five cases of this kind, and Coley published an account of nine cases with four cures. Among the latter was a very remarkable case of Bull's: Round-celled sarcoma of the neck, with five recurrences in three years; the entire removal was impossible in the last operation, and a wound twelve and a half by five centimetres resulted, which soon became filled up with masses of sarcoma tissue. Fourteen days later two attacks of erysipelas took place, whereupon the wound rapidly cicatrised. Seven years afterwards the cure was found by Bull and Coley to be perfect. Langenbuch has also published an instance of a great number of recurrent sarcomata of the skin which were caused to disappear by this means. One must, however, constantly bear in mind that the patient may die as a result of the inoculation of erysipelas, and hence it is one's duty to warn the patient or his friends of the danger before this procedure is adopted. The various other methods of treatment of sarcoma are described in the Special Surgery, and in connection with the treatment of tumours in general.

§ 129. **The Epithelial Tumours.**—The epithelial tumours include the papilloma, the epithelioma, the adenoma, and the carcinoma.

I. **Papilloma.**—The papilloma results from hyperplasia of the epithelial layer of the skin and mucous membranes, with a corresponding new growth of connective tissue and blood-vessels. It is really a mixed

tumour consisting of newly formed connective tissue and epithelium. A distinction is made between a hard and a soft papilloma.

The hard, horny papillomata include, in the first place, warts (verrucæ), which are the well-known growths of the papillæ of the skin and epidermis, about the size of a bean or a pea. They are essentially a product of an overgrowth of the epidermis, which becomes horny, and often occur in great numbers without any known cause, especially on the hands, though in rare instances a diffuse warty hypertrophy of the cutis has been observed on the scalp (see Fig. 431). Mention should also be made of the onychoma (hypertrophy of the nails), calluses (clavi) resulting from a circumscribed hyperplasia of the epidermis, and the cutaneous horns (cornea cutanea), which are excrescences on the skin due to a new growth of horny epithelial cells (true epitheliomata). The cutaneous horns occasionally originate from the sebaceous glands or from open atheromata (sebaceous cysts). They are most common on the forehead and nose in old people. Brinton has collected fifteen cases of cutaneous horn of the penis, besides one that came under his own observation. They sometimes occur in great numbers (Fig. 432), not infrequently being curved, and may attain a length of from twelve to sixteen centimetres or more (see Special Surgery). It should be noted that occasionally benign cutaneous horns which consist only of horny epithelial cells change into carcinomata.

Fig. 431.—Warty hypertrophy of the scalp occurring in a woman twenty years of age (Billroth).

Fig. 432.—Multiple cutaneous horns, from twelve to sixteen centimetres in length, on various portions of the body of a seventeen-year-old girl (Bäthge).

In this category belong also the tumour-like thickenings of the epidermis called keratomata, which are most commonly found on the sole of the foot and the palm of the hand, and are not infrequently inherited by all the branches of a family for many generations (Unna). They result from a thickening of the epidermis, though the whole cutis also takes part in the hyperplasia. They often change into real cutaneous horns or become combined with other new growths like angeiomata (angeio-keratoma). Unna recommends for their treatment the use of a ten-per-cent. ethereal solution of salicylic acid, or the latter made into a plaster.

Ichthyosis (from ἰχθύς, fish) is a scaly thickening of the epidermis, usually congenital, over the entire surface of the body. Hystricismus (from ὕστριξ, hedgehog) is a disease in which there is a formation of thorn-like excrescences on the skin, due to hypertrophy of the papillæ and the epidermis. It is likewise, as a rule, congenital in origin.

The soft papilloma is characterised by a soft stroma, a marked vascularity, and a very moderate growth of epithelium, which does not become horny. They occur on the skin and mucous membranes, generally of the bladder, rectum, and uterus. The cauliflower excrescence of the vaginal portion of the cervix is a soft papilloma. In the rectum, uterus, and in other mucous membranes, the soft papilloma forms growths which are analogous to the above-mentioned mucous polyps. The polyps which are covered with epidermis, rete Malpighii, cutis, and hair, and occur in the pharynx, for example, originate, according to Arnold, from strayed embryonic cells and probably belong to the teratomata. The soft papillomata not infrequently change into sarcoma and carcinoma. The condyloma acuminatum found on the mucous membrane of the vulva, vagina and penis is also a soft papilloma; the broad condyloma (condyloma latum) is a papillary growth with a broad base, and often occurs about the anus in syphilis.

The various kinds of papilloma should be treated according to the general rules already laid down. Warts should be removed by cauter isation with red, fuming nitric acid (not chemically pure), after paring off the epidermis with a knife. They are then usually cast off on the fifth or sixth day, or, if not, they may have to be cauterised again. Repeated applications of salicylic or iodoform collodion with a brush, as well as of a paste made with arsenic, are also exceedingly serviceable. By the use of these medicaments the wart gradually drops off in the form of a dried-up eschar. The same treatment may be used for calluses and corns, though they can be removed more simply by the knife after softening them in salt water.

Molluscum Contagiosum or Epithelioma Molluscum.—Authorities differ widely in their views as to the nature of molluscum contagiosum. It is a peculiar skin disease in which there is a development of numerous nodules, varying in size from that of a pea to that of a hazel-nut or larger, generally located on the uncovered parts of the body and on the genitals. The small tumours are epithelial in character, and are said by Hebra to be caused by an accumulation of cells in a sebaceous gland, while Virchow thinks the growth of epithelial cells begins in the hair follicles, and Bizzozero, in the interpapillary portions of the rete Malpighii. They contain characteristic bodies, partly free and partly enclosed in cells which resemble swollen starch, and which, according to Leber, are degenerated epithelial cells, although Klebs and Bollinger maintain that they are parasitic (psorosperms, coccidia). The disease

is contagious, and not infrequently occurs in the form of epidemics, especially in children's asylums. Isolated cases are rarely met with. The treatment consists in simply pressing out the small tumours with the finger nail; the larger ones may require the use of the sharp spoon. Healing takes place without the formation of a cicatrix.

II. **Adenoma** (*Glandular Tumour*).—The adenomata correspond in their structure to that of glands (Fig. 433), but the term does not include simple hypertrophy of the latter, being used to designate only the true new growths which are separated from the surrounding tissues in the form of circumscribed nodular tumours. Even adenomatous degeneration of an entire organ can be easily distinguished from a general glandular hyperplasia. The adenomata form both hard and soft tumours. Microscopically, a distinction is made between tubulous and acinous or alveolar adenoma. They are very often combined with the formation of cysts. The adenoma is in itself not malignant, but it frequently changes into a destructive form—i. e., it becomes a carcinoma, in that the growing tubules penetrate the surrounding parts, take on an atypical growth, destroy the neighbouring tissues, and, by involving the lymphatics and blood-vessels, give rise to metastases. The commencement of a change like this from adenoma to carcinoma has been called adenoid. There are, however, malignant adenomata, which remain true adenomata, with a distinct separation of the glandular epithelium from the stroma, but which nevertheless cause local destruction of tissue and give rise to metastases. The adenoma of the rectum is an example of this variety. The adenoma is found in various glandular organs, in the skin (sebaceous glands, sweat glands), in the respiratory and digestive tracts, in the genital organs, the mamma, thyroid, and salivary glands, liver, kidneys, etc.

Fig. 433.—Adenoma mammæ alveolare or acinosum. × 30.

The treatment of adenoma consists in prompt extirpation of the tumour, as it is to be looked upon as an early stage of carcinoma, into which it frequently develops. With reference to the technique of the operation for removal of adenoma of the thyroid (goitre) and of laparotomy for removal of ovarian adenoma, particulars will be found in the Special Surgery.

III. **Carcinoma** (*Cancer*).—A carcinoma originates from the atyp-

ical growth of epithelial cells, the latter forming the main part of the tumour, though every atypical growth of epithelium is not cancer. In inflammatory processes and in the healing of wounds, an atypical growth of epithelial cells takes place in the form of cylinders or bulbs, but their growth is limited and they do not infiltrate and destroy the surrounding tissues. It is quite different with carcinoma. Here the epithelial cells keep on growing unhindered; they infiltrate the surrounding tissues in the form of cell nests, displacing and destroying them. The cellular cylinders and nests, which are made up of proliferating epithelial cells, lie embedded in a partly old and partly new formed connective-tissue stroma (Fig. 434). As a result of the unimpeded growth

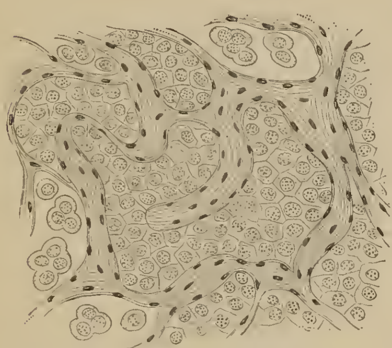


FIG. 434.—Carcinoma mammæ simplex. × 200.

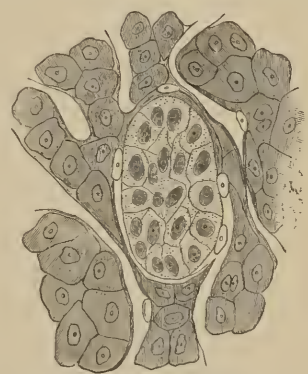


FIG. 435.—Section through a commencing embolic cancer in a liver capillary resulting from an adeno-carcinoma of the stomach (Ziegler). × 300.

of the carcinoma, or rather of the groups of epithelial cells, the latter invade the lymph and blood vessels and produce, by means of transported living cancer cells, secondary nodules in the nearest lymph glands, and later in the various internal organs (Fig. 435). This power of forming metastases—in other words, of causing a general infection of the body—is characteristic of cancer. As regards the development of metastases in the lymph glands, it has been shown that the epithelial cells which make their way through the afferent lymphatics into the lymph sinuses multiply by caryocinesis; that they, by their continuous growth, mechanically displace the glandular tissue; and that endothelial cells and lymph cells do not change into cancer cells. The general cancerous infection can lead to such extreme exhaustion that the patient succumbs to the cancerous cachexia.

In the skin the carcinoma arises from the cells of the rete Malpighii or from the cutaneous glands; an infiltration of the corium with

epithelial cells gradually takes place, the cells being collected in single groups, cylinders, or nests which lie in a partly old and partly new formed connective-tissue stroma. In the glands a proliferation of the glandular epithelium first takes place, forming an adenoma; then these proliferated cells invade the tissue surrounding the lobes of the glands, where they continue to grow unimpeded. The shape of the proliferated epithelial or cancer cells is not constant, but depends upon the location of the cancer. The cells of an epithelioma of the skin correspond in general to those of the rete Malpighii, while in a carcinoma of the stomach they have a cylindrical form, etc. Retrograde metamorphoses are very common in carcinoma because the nutrition of the great numbers of cancer cells is insufficient. Hence fatty, mucoid, colloid, or cystic degeneration as well as calcification are of frequent occurrence. The degenerative changes in the central portions of a carcinoma and the adhesion of the integument often give rise to an umbilicated drawing in or depression of the skin. Superficial carcinomata, especially those which involve the skin, mucous membranes, or mamma, are extremely apt to break down and form extensive sloughing, punched-

Fig. 436.—Large ulcerating carcinoma of the lower jaw and cheek occurring in a patient suffering from lupus (Esmarch).

Fig. 437.—Pronounced destruction of the face by an epithelioma of the skin (Billroth).

out cancerous ulcers (Figs. 436, 437). Bleeding not infrequently takes place, manifesting itself in the form of circumscribed hæmorrhages or blood cysts, or, in other cases, a carcinoma may by degrees erode a large vessel, and thus suddenly lead to a profuse loss of blood, which may prove fatal.

Occasionally a primary carcinoma is found in a multiple form.

Schimmelbusch has collected these rare cases from literature showing that multiple carcinomata of the skin are the most common, and may develop from a soot or tar eczema, from senile seborrhœa and xeroderma pigmentosum, ulcer of the leg, etc. In some instances they probably originate by inoculation from one part of the body to another, though in addition to these multiple carcinomata of inoculation others occur which, according to Schimmelbusch, are to be regarded as independent tumours appearing simultaneously. Mandy has reported a carcinoma of both ears which came under observation in Bruns's clinic.

The following different varieties of carcinoma have been described.

1. *Flat Epithelial Cancer or Epithelioma.*—The epithelioma of the skin, or cancroid, appears in the form of diffuse thickenings or nodular, warty, often ulcerating, elevations. On section, the alveolar structure can usually be seen with the naked eye and the epithelial nests or cylinders can be squeezed out or scraped from the cut surface with the knife. Some epitheliomata remain superficial, while others grow into the deeper parts. The superficial variety, the cancroid or ulcus rodens, as it is called, which is more flat than the other, arises mainly from the rete Malpighii, while the growth having deeper attachments take its origin to a greater extent from the sebaceous glands.

Epitheliomata also develop on mucous membranes that have a pavement epithelium (mouth, pharynx, œsophagus, vagina, uterus, bladder).

2. *Cylindrical-celled Carcinoma.*—The carcinoma with cylindrical cells is found particularly in the mucous membrane of the digestive tract and uterus; it has a soft consistency and is very likely to undergo a mucoid degeneration.

3. *Carcinoma with Gland Cells (Carcinoma Glandulare).*—This is found in various glandular organs (mamma, liver, salivary glands, kidneys, testicles, etc.), and varies microscopically according to the organ affected.

4. *Other Varieties of Carcinoma.*—According to the shape, consistency, and other properties of the cancer the following varieties may be differentiated. The scirrhus is a very hard, tough carcinoma with small and few cancer cell nests lying in a dense stroma. The soft carcinoma (carcinoma medullare) is the opposite of the scirrhus, being rich in cells and having a soft stroma. The pigmented or melano-carcinoma, like the melano-sarcoma, is a brown or black tumour, which is, however, much less common than the latter. The pigment is likewise situated in the cells.

The so-called giant-celled carcinoma is in some instances made up of true giant cells, while in others, the increase in the size of the cells is due to mucoid or dropsical degeneration.

The colloid cancer (carcinoma gelatinosum) occurs especially in the intestine and breast, where it forms a transparent gelatinous tumour as a result of the mucoid or gelatinous degeneration of the cell-nests. The carcinoma myxomatodes originates either from the mucoid degeneration of the stroma and often of the cancer cells, or from the combination of a myxoma with a carcinoma (myxo-carcinoma). Occasionally colloid degeneration of the

cancer cells gives rise to homogeneous spherical bodies which are found in the cancer nests.

The external appearance of carcinoma is variable. Most commonly there is a formation of circumscribed nodules; less often the disease takes the form of a more diffuse, superficial infiltration and induration, or of papillary growths with large, branching papillæ (villous cancer—e. g., of the bladder). Occasionally the skin, as in the region of the mamma, becomes diffusely diseased, as hard as a board, and infiltrated by a great number of small and large nodules (cancer en cuirasse).

Etiology of Carcinoma.—Local irritations of a mechanical and chemical character are very important factors in the production of a carcinoma. Hence one is most likely to develop in those parts of the body where mechanical and chemical irritations most commonly occur, as in the skin, lips, mouth, œsophagus, and in other parts of the digestive tract where normally narrow places exist, such as, for example, the œsophagus at the point where it passes through the diaphragm, the cardiac and pyloric regions of the stomach, the flexura sigmoidea, the rectum near the sphincter tertius, and the anus. In men, cancers of the skin, lips (almost always the lower lip), mouth, and rectum are the most common; while in women the glandular carcinomata predominate, and those of the mamma and the uterus are especially frequent. Carcinoma of the stomach is equally common in women and men, and is very likely to develop from a cicatrised gastric ulcer. The epitheliomata of the lips, especially the lower lip in men, have been ascribed to smoking, to frequent irritation from unskilful shaving, etc., and the epitheliomata of the tongue and mucous membrane of the inside of the mouth to the irritation produced by smoking and chewing tobacco, or by the sharp edges of the teeth. The epitheliomata of the scrotum, observed in chimney-sweeps and workers in tar and paraffine, are explainable on the same principle. Analogous irritating chemical substances are present in soot, tar, and paraffine, just as in tobacco-smoke, tobacco-juice, and tobacco-ashes—i. e., various products of dry distillation, especially carbolic acid. These irritating substances become deposited in the skin of the scrotum, and sometimes give rise to cancer. I observed in a worker in paraffine who had a characteristic chronic paraffine dermatitis with the formation of scabs and pustules on the hands and forearms, the development of a typical carcinoma with metastases at the site of one of the scabs. Fig. 438 shows the hand of this patient, who finally died of general carcinosis. Two years previously I had removed from the same man a paraffine epithelioma of the scrotum, which did not recur. Chronic inflammations in various parts of the body often give rise to carcinoma. Cancer will also be

found in conjunction with benign neoplasms, like fibroma, atheroma, cutaneous horns, etc., and in cicatrices. According to different authors, its development is favoured by a too plentiful meat diet, as the inhabitants of southern countries, who live largely on vegetable food, and the herbivorous animals are said, as compared with the carnivora, to suffer very seldom from this disease. A predisposition to carcinoma often appears to be inherited. It is essentially a disease of advanced life. At this period a slowly increasing atrophy of the stroma, in a certain sense, takes place, causing the skin, for instance, to become shrivelled and thin, and rendering it easier for the epithelium to make its way into the stroma as a result of mechanical or chemical irritations. A "boundary war," as it were, begins between epithelium and connective tissue, which in carcinoma ends in a victorious entrance of the epithelium into the less resistant stroma.

Fig. 438.—Hand of a worker in paraffine, showing chronic dermatitis with a formation of pustules and crusts and papillary growths; carcinoma of the forearm starting from one of these inflamed spots; amputatio antibrachii and death from general carcinosis.

What is the cause of the unlimited energy and power of growth possessed by carcinoma? Hansemann attempted to answer this question in the following way: While it is an established fact under normal conditions that in the indirect nuclear division the chromatin or nuclear fibrils divide into exactly equal-sized groups, Hansemann found that in malignant epithelial tumours (carcinoma) a division often took place into two unequal groups; and he thinks that this asymmetrical nuclear division, which belongs only to the malignant epithelial growths, is due to the fact that the cell eliminates certain parts of its protoplasm in the same way that the ovum, by expelling the directing or polar globules, frees itself of certain elements that are present in too large quantities. In this way the cancer cells attain an independence like that of the ovum, and to this is due their energy of growth and power of further development as metastases in different parts of the body.

Importance of Micro-organisms in the Etiology of Carcinoma.—Scheuerlen (Deutsche med. Wochenschrift, 1887, No. 48) attempted to make pure cultures of specific bacilli and spores from a carcinoma, and inoculate them

into animals. He used for his experiments ten mammary carcinomata, and made on the average twenty inoculations for each case, among which there were always at least seven successful ones. The microscopic examination of the pure cultures showed, in addition to bacilli from 1·5 to 2·5 micromillimetres in length and 0·5 micromillimetre in breadth, a number of almost as large ovoid, translucent, and greenish-coloured bodies (spores). The bacilli and spores have a special kind of self-locomotion; the former can be stained by all methods and immediately decolourised by alcohol. The spores can be stained in the same way as tubercle bacilli. Scheuerlen could not find with certainty bacilli or spores in sections of carcinomatous organs, but he did find them in the cancer juice, mostly outside the cancer cells. Pure cultures of cancer bacilli grow best upon agar, potato, infusion of meat peptone, or cabbage, and more slowly upon gelatine. In agar a streaky cloud is developed along the line of puncture, similar to the one caused by the bacilli of mouse septicæmia. By injection of media containing cancer bacilli into the mammary glands of six bitches, hard cancer nodules were produced from which pure cultures of characteristic bacilli and spores could be obtained.

Other authorities, such as Pfeiffer and Sanarelli, have also found Scheuerlen's bacilli in carcinoma, but attempts at inoculation proved entirely unsuccessful, and the majority of writers are of the opinion that there is at present no ground for considering the questionable bacilli to be the cause of cancer. They are much more inclined to think that it is merely an innocent, accidental saprophyte. Pfeiffer maintains that the bacillus is identical with the proteus mirabilis.

Schill found in sections and in the juice of carcinoma and sarcoma little rods containing two dots, both ends of which appeared, after staining by Gram's method, as small points of a deep violet colour, which were joined by a transparent thread. Besides these a mould-fungus was present.

Some interesting investigations have been made by Thoma, who found in carcinomata of the rectum, the stomach, and the breast peculiar unicellular structures within the cell nuclei, having a diameter of from four to fifteen micromillimetres, spherical or oval in shape, or more like a whetstone, and consisting of protoplasm and a nucleus. He is inclined to think that these bodies are encapsulated coccidia. Whether they are to be looked upon as the cause of carcinoma cannot, as Thoma himself says, be decided until further exact tests have been made. Many other investigators have seen similar bodies in the nuclei or protoplasm of epithelial cells in carcinoma, some looking upon them as psorosperms, and others as altered and degenerated epithelial cells. The question whether protozoa really are present in carcinoma has been discussed very fully of late, and the matter is one of great interest. But the occurrence of coccidia in carcinoma has become more and more doubtful recently, and they are thought by many to be products of the degeneration of cells (Le Dentu, Karg, author). Schütz thinks it very probable that some of the bodies originate from the red blood-cells. It is evident that we have to deal here with morphologically and genetically different forms of cells as well as of cellular and nuclear changes, including Altmann's cell granula.

The fuchsine bodies described by Russell and others as characteristic of carcinoma and thought to be blastomycetes are, according to Klein, Altmann,

and Karg very large cell granules. The parasitic nature of carcinoma is at present still an open question.

The Transmissibility of Carcinoma.—The question whether carcinoma is transmissible or not is of the greatest importance as regards its etiology. That it is has, in fact, been experimentally proved in the case of mice and rats by Novinsky and Morau, who also succeeded in causing metastases in the internal organs of the former animal. It has also been noted that carcinoma is occasionally transferred from one part to another of the same body, or from one person to another. Hahn cut skin grafts from some of the numerous disseminated cutaneous nodules of a cancer existing on the thorax of a woman and planted them on other portions of her body, and found that they went on growing and developed into similar cancers. Cornil and Frank have likewise seen successful inoculations of carcinoma in man. It has repeatedly been observed that malignant tumours (carcinoma and sarcoma) have resulted from a simple transference of living tumour cells during an operation, and hence this means of infection may occasionally be the cause of recurrences after the extirpation of such a neoplasm. Billroth saw an isolated carcinoma form in the cicatrix in the overlying abdominal wall after extirpation of a similar growth (which was not adherent to the surrounding parts) from the pylorus. Becker and Czerny have also noticed instances of cancerous inoculation of a cicatrix following an operation. Bergmann saw a carcinoma of the upper and lower lips at exactly opposite points, a circumstance which made it probable that one was the cause of the other. There are many similar cases recorded, all of which indicate that carcinoma originates from infection by contact, and may develop in a person who comes into close relations with another who has the disease; husbands, for example, have been known to acquire one of the penis from wives with a cancer of the uterus (Czerny, Tross, etc.). This transmissibility possessed by carcinoma does not prove, of course, that the poison of cancer depends upon micro-organisms; on the contrary, it seems very probable that the transmission, like the metastases, is accomplished by the living cancer cells.

Course, Prognosis, and Diagnosis of Carcinoma.—Carcinoma runs a chronic course extending over months and years. Its varying energy of growth and its location are factors of great importance in determining how rapidly or slowly the disease will progress. In rare instances a more or less acute general carcinosis takes place, causing, in a few weeks, metastases and marked cancerous cachexia. The latter is very much increased by rapid growth of the primary and secondary cancer nodules, by ulceration and sloughing, by stenoses that interfere with the entrance of air or food, by disturbances of digestion, etc. Ulceration is especially prominent in epitheliomata of the skin. Cancerous ulcers are, as a rule, irregular in form, and their edges and bases, as well as the surrounding tissue, are hard and indurated. The superficial ulcerating epithelioma of the skin, the so-called cancroid or ulcus rodens, runs comparatively the most favourable course, in that it spreads slowly over the surface, has less tendency to involve the

deeper parts, and only leads late in its course to infection of the nearest lymph glands.

According to Klemperer, the metabolism of cancerous individuals is characterised by a pronounced destruction of albumen, the viscera undergoing fatty degeneration and the blood showing a marked diminution in its percentage of carbonic acid; and hence he infers that carcinoma causes a systemic intoxication by means of certain poisonous substances—a conclusion which is not accepted by Minkowski. According to Müller, the cancerous cachexia resulting from the increased destruction of albumen, the diminution of the chlorides in the urine, and the loss of weight, is similar to the febrile processes and cachexiæ present in long-continued malaria, leucæmia, and pernicious anæmia. The cause of the abnormal destruction of albumen in cancerous individuals probably lies in the poisonous action of the products of metabolism of the carcinoma. As a result of the accumulation of these products of metabolism and of the insufficiency of the kidneys, symptoms of coma carcinomatosum and death may supervene (see pages 743, 744).

The *prognosis* of cancer is, as we have already clearly stated, very unfavourable. Complete cures are rare, even when the carcinomata are extirpated very early in their course. As a rule, one recurrence follows another until the patient succumbs to general carcinosis or exhaustion. We make a distinction, based upon their mode of origin, between continuous and regional recurrences; the former spring from portions of the primary tumour which were left behind at the time of the operation, while the latter (regional recurrences) are to be looked upon as independent new tumours in the cicatrix or its vicinity. The second kind sometimes make their appearance only after the lapse of years. All recurrences which occur later than two years after the operation should be considered, according to Snow, new independent tumours resulting from new injurious agencies.

The *diagnosis* of carcinoma is in general not difficult if what has been said be borne in mind. A differential diagnosis may have to be made from tubercular and syphilitic growths. A careful microscopic examination of an excised portion of the tumour will usually clear up any uncertainty. If syphilis is suspected, antisyphilitic treatment should be begun (iodide of potassium, mercury, etc.), and when the latter disease is present such a method of treatment will be successful, but not in cases of carcinoma.

Treatment of Carcinoma.—The treatment of carcinoma consists in as early an extirpation as possible. During the later stages an attempt should at least be made to check its course and improve the general condition of the patient. In extirpation with the knife as much of the

healthy tissue as can be spared should be included, so as to leave no tumour cells behind. The nearest lymph glands must always be thought of; thus, in every amputation of the breast, for example, the axilla should be opened and the glands and all the fat removed, even though no enlargement of the former can be felt from without. After the axilla has been cut into, slightly enlarged lymph glands are often found in cases where they were not suspected. Complete cures sometimes result from an early, careful extirpation of a carcinoma, and if no recurrence appears within one and a half to two years the patient is to be regarded as probably entirely freed from his disease. I have, however, occasionally seen recurrence take place three years after the first operation. One generally occurs sooner or later, and after extirpation of this, the carcinoma very frequently reappears in a still shorter time, making it seem in many cases as though recurrences were hastened and increased in virulency by each succeeding operation.

The different methods of operation for carcinoma with the knife, galvano-cautery, thermo-cautery, etc., are described in the chapters on general surgical technique, and the extirpation of carcinomata in different parts of the body—the skin, breast, mouth, stomach, intestine, uterus, etc.—is described in the Special Surgery.

The treatment of inoperable carcinomata is symptomatic. According to the nature of the case, a trial may be made of the various methods already mentioned in connection with the treatment of tumours in general. These include, in addition to a general strengthening regimen, parenchymatous injections, the arsenic treatment, and circumcision with the thermo-cautery in order to diminish the growth, pain, and final sloughing of the carcinoma. In sloughing cancers, use may be made of the sharp spoon, thermo-cautery, and dressings filled with deodorizing substances, such as acetate of aluminium, carbolic acid, bichloride of mercury, iodoform, and naphthaline. Narcotics in the form of subcutaneous injections of morphine are often indispensable. The inoculation of erysipelas has already been spoken of on page 771. It is frequently necessary to perform an operation for the treatment of the sequelæ of an inoperable carcinoma; a tracheotomy may be required, for example, in carcinomatous stenoses of the larynx, or the formation of an artificial anus in carcinoma of the intestine. Whether the growth of the disease is influenced by the transplantation upon it of healthy skin (Goldmann) cannot as yet be definitely decided.

Amongst the medicinal preparations that have recently been well spoken of, the following should be mentioned: Mosetig-Moorhof recommended parenchymatous injections of aniline dyes (methyl violet or pyoktannin 1 to 500 aq. dest.), but I have seen no good results from

its use. Clay (Birmingham) speaks well of the action of turpentine (in the form of the essence made by Southall and Barclay in Birmingham, two teaspoonfuls three or four times a day, with pills of sulphur and sulphate of copper, etc. ; also local injections into the tumour). Strohbinder uses parenchymatous injections of tannic acid into the carcinomatous growths (one hypodermic syringeful a day). Glycerine and resorcin have also been used locally, decoctum Zittmanni (decoctum sarsaparillæ compositum) internally, and chalk, powdered oyster-shells, and condurango-bark both internally and locally—all of which are probably useless. Esmarch and others have recommended for cancer patients a diet consisting of but little nitrogenous matter.

§ 130. **Cysts—Atheromata, Teratomata, Cyst-formation in Different Tumours.**—The formation of cysts takes place, as we have already said,

Fig. 439.—Cysto-sarcoma of the femur (Busch).

Fig. 440.—Proliferating follicular dental cyst of the lower jaw in a peasant thirty-two years of age (Bryk).

in many different kinds of tumours, especially adenoma (cysto-adenoma), fibroma (cysto-fibroma), and sarcoma (cysto-sarcoma), as a result of softening.

The proliferating cystoma of the ovaries, kidneys, or mammæ, in which a new production of cysts takes place, belongs to the class of the true cystic tumours. But, in the main, these proliferating cysts are adenomata; a proliferation of cells first occurs, and, secondarily, the formation of cysts as a result of mucoid and colloid degeneration of the cells. This continues, until finally very large tumours are de-

veloped, particularly in the ovaries. Cystic goitres also begin as adenomata.

Bone cysts are, as a rule, either enchondromata, fibromata, or sarcomata, which have undergone cystic degeneration (Fig. 439), or true proliferating cystic tumours. To the latter belongs that cystic degeneration which often simultaneously attacks all the bones of the body, and is perhaps to be regarded as a constitutional disease. Bramann found a multiple formation of cysts in a great number of the bones of a woman thirty-four years old, who had osteomalacia. Many bone cysts are probably due to inflammatory processes or hæmorrhages (Schlange). The cysts of the jaw and teeth (Fig. 440) arise either from the periosteum or from the dental follicles as a result of disturbances of development. Here, also, the proliferation of cells takes place first, and then a progressive formation of cysts follows. A large number of cysts, originating in a great variety of ways, are congenital; these have been described very fully by Lannelongue and Archard. Other cysts are due to parasites, such as echinococcus and cysticercus cellulosæ, and are found in various organs of the body.

The contents of the cysts are serous, mucous, or bloody. A distinction is made between simple and compound or multilocular cysts. The interior of the latter is divided off by septa, and, in some instances, new cysts form in the walls of the old ones.

The retention cysts do not belong to the true tumours, as in these cases an abnormal new growth of cells does not occur, but only an accumulation of secretion. With Virchow, we divide the retention cysts into (1) mucous cysts, (2) follicular cysts, and (3) retention cysts, starting in the excretory duct or the acini of large glands. Mucous cysts, which result from the retention of the secretion of the mucous glands, are found especially in the mucous membrane of the lips, the cheeks, the antrum Highmori, the respiratory and digestive tract, the vagina, the uterus, etc. The follicular cysts include the comedones, those well-known little spots in the skin, often of a black colour, which are plugs or secretion in the hair follicles, and the milium resulting from a similar accumulation of secretion in the sebaceous glands. The atheromata or sebaceous cysts are retention cysts of the hair follicles. The latter continue to form their secretion, and consequently the sac becomes more and more tense; and thus are developed in the skin the well-known tumours which vary in size from that of a small pea to that of a fist or a child's head, and contain epidermis, fat, and crystals of cholesterin. A second variety of atheroma is situated not in the skin, but deeper down in the subcutaneous tissue. These deep subcutaneous atheromata are probably the result of separated embryonic remnants

of skin tissue which contain sebaceous glands or groups of epithelium belonging to the epidermis. In the latter case they might be called epidermoids (Franke). Franke thinks that atheromata are not retention cysts of the skin follicles, but represent true new growths which have sprung from embryonic cells. The atheromata sometimes gradually break through the integument, and become complicated by inflammation, suppuration, or even epithelioma (Fig. 441). Hence extirpation of atheromata is always indicated. Cutaneous horns occasionally develop from open atheromata with fistulæ.

Among the retention cysts which arise from the excretory ducts or acini of large glands may be mentioned the retention cysts of the liver, the mamma, and the kidney; also the so-called ranula under the tongue near the frenulum resulting from the closure of the excretory ducts of the submaxillary and sublingual glands, and particularly of the Blandin-Nuhn glands—two mucous glands situated near the tip of the tongue.

Fig. 441.—Woman fifty-nine years of age with atheromata of the hairy portion of the scalp; a typical carcinoma developed in a cyst which suppurated on the top of her head.

Cysts are, moreover, found in structures which do not persist after the birth of the fœtus; examples of these are branchiogenic cysts of the neck, cysts of the urachus, etc.

We have already mentioned the occurrence of blood and lymph cysts due to a gradual dilatation of blood- and lymph-vessels.

By cholesteatoma is meant either an atheroma or a dermoid cyst, with characteristic, often silky white contents which are made up of fat, cholesterin, and groups of cells which shine like mother-of-pearl. The cholesteatomata are found especially in the brain and its meninges; also in the ovaries, in the subcutaneous cellular tissue, and in bone (petrous portion of the temporal). According to Eppinger and others, the cholesteatomata are essentially endotheliomata (see page 768). Glaeser examined one which was found on the base of the brain, and came to the conclusion that the cells of the cholesteatoma develop from the endothelia of the lymph spaces of the arachnoid by growth and concentric division. Kuhn is disposed to think that the cholesteatomata of the ear are principally congenital in origin. Politzer found small roundish bodies in the mucous membrane of the ear which increase in size and lead to the formation of these tumours. The suppuration and sloughing which accompany cholesteatomata of the ear

are secondary conditions, and not, as Habermann thinks, the cause of their development. These sequelæ lead not infrequently in cholesteatomata of the ear to death of the patient; and hence Kuhn emphasises the necessity of a radical removal by osteotomy, if it is required, of the portion of the bone in question (mastoid process). The etiology of cholesteatomata of the middle ear and the meatus is probably complex; some of the cases are certainly endotheliomata, while others are the result of a simple proliferation of epithelial cells, or a change of epithelial cells into epidermis. The etiology of cholesteatomata has an extremely interesting bearing upon the etiology of tumours in general, showing, as it does, that tumours can arise from the cells of the mesoderm which correspond exactly to those that originate from epithelium.

The treatment of cysts depends largely upon their location and their cause; it consists in extirpation, puncture, incision, parenchymatous injection of various fluids, such as absolute alcohol with or without tincture of iodine (see page 745, Treatment of Tumours in General), etc. The treatment of cysts of the different parts of the body is described in the Text-Book on Special Surgery. The extirpation of smaller atheromata is best accomplished by introducing a probe or a small instrument shaped like a spatula, or a pair of Cooper's scissors, into the cutaneous incision, freeing the atheroma on all sides, and finally taking out the uninjured cyst with its capsule *in toto.* Care must be taken to always remove the whole of the atheroma, which should not be opened at the time the cutaneous incision is made; this may be done by cutting through the skin first at the base of the tumour, and after separating the latter from the surrounding parts with a probe, enlarging the original incision with scissors sufficiently to permit the loosened cyst to be enucleated.

Teratomata are congenital tumours or malformations which are made up of a great variety of tissues. They include both the double monstrosities, in which one embryo is rudimentary and united to the other, and malformations which have taken place in a single fœtus. All sorts of structures have been found in congenital tumours and cysts. Kümmel discovered in a congenital coccygeal neoplasm a body that resembled an eye which was similar to one found by Marchand and Baumgarten in an ovarian cyst.

The dermoid cysts also belong in this class; they have an inner wall which is analogous to the skin, and may occur in organs where skin is not normally present. They are most commonly found in the ovary, and also in the peritonæum, neck, orbits, nose, and in the sacral and coccygeal regions. The wall of the cyst consists, as we have said, of epidermis and corium, with sebaceous glands, hair follicles, and less

often sweat glands. The contents usually consist of a fatty, yellowish or whitish, greasy mass, together with hairs, cartilage, bone, and even teeth. In very rare cases, brain, nerve, and muscle tissue or structures resembling extremities have been found. Occasionally the contents are oily (oil cysts). Kocher and Streit have laid emphasis upon a peculiarity possessed by these tumours—when not filled too full—of retaining for a considerable length of time any change of form which is given them. This is due to their homogeneous cement-like contents. If epithelial cells and masses of fat are mixed with a large amount of hair, a peculiar crepitation may be felt on palpation of the tumour (Kocher). The dermoid tumours develop from stray cutaneous cells which have been inverted, as in the closure of embryonic clefts. At the same time cells of the entoderm may become displaced or separated.

Polypous appendages are sometimes found upon different parts of the surface of the body. They are to be looked upon as abnormal displacements of tissue or malformations depending upon an imperfect closure of embryonic clefts. Such tumours or cutaneous appendages, occasionally containing cartilage, are found in the vicinity of the lines of closure of the dorsal or ventral clefts, or near the face, ears, neck, anal region, or the rhaphe of the perinæum (Chiari).

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